# TECHNICAL REPORT BRL-TR-3001

# BRL

# A LIBRARY OF DIGITIZED FLIGHTPATHS

## JOSEPH K. WALD

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This report contains pictures of a variety of flightpaths developed from data collected over the last few years from several Army field tests of air defense weapon systems. The raw test data was subject to a smoothing process to produce flightpaths suitable for use in simulation validation efforts and effectiveness analyses.

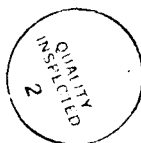| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT<br>☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS | 21. ABSTRACT SECURITY CLASSIFICATION<br>UNCLASSIFIED |
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# A Library Of Digitized Flightpaths

Dr. Joseph K. Wald

## I. INTRODUCTION

Digitized flightpaths are required input to detailed simulation models for a number of air defense weapon systems, both guns and missiles. Generally speaking, the more detailed and extensive the modeling of the fire control in such models, the more detailed and realistic the flightpaths should be. Sometimes mathematically generated flightpaths are used, but unless these are constructed in a rather sophisticated way, they lack the proper frequency content and plant noise reflected in flightpaths flown by real pilots in real aircraft.

In this report we present pictures of a variety of flightpaths we have collected over the last few years from a number of Army field tests of air defense weapon systems. After undergoing a smoothing process, these flightpaths have been used in simulation validation efforts and effectiveness analyses.

## II. METHODOLOGY DESCRIPTION

The raw data for the flightpaths contained in this collection were recorded in tests conducted at Ft. Bliss, Texas and Ft. Hunter Ligget, California. The rotary wing aircraft were typically UH1s and the fixed wing aircraft were typically A7s with an occasional F100 or A10. The equipment used to collect the raw target position data was usually radar or cinetheodolites. To remove the "measurement noise" from the raw data, we used a double sweep optimal smoothing technique[1] that simultaneously produces position, velocity, and acceleration estimates in the x, y, and z coordinates. For each flightpath, the time interval between successive data points is 0.05 seconds.

There were typically no attitude sensors on board the aircraft during these tests, so we had to calculate the aircraft attitude angles (roll, pitch, and yaw) analytically. For the fixed wing aircraft, we added the target attitude angles under the assumption that the longitudinal axis of the aircraft coincided with its velocity vector - i.e., there was no angle of attack. For the aircraft and flight profiles under consideration, this was generally a good assumption. We made the same assumption in those cases in which the helicopter had a significant forward velocity. For the hovering helicopters, we made the assumption that the helicopter had no pitch or roll, and that the aircraft would orient itself to present a "nose-on" view to its target, which was presumed to be at the origin of the coordinate system.

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[1]Scheder, Robert A., A Computer Program For Double Sweep Optimal Smoothing (U), U.S. Army Materiel Systems Analysis Activity Technical Report No. 246, January, 1979. UNCLASSIFIED.

# III. THE FLIGHTPATHS

There are sixteen flightpaths in this collection, nine flown by fixed wing aircraft and seven by helicopters. A number of different ground attack maneuvers are represented in this collection. These are summarized in Table 1.

| TABLE 1. Flightpath Summary. | | |
|---|---|---|
| Flightpath | Aircraft | Maneuver |
| 1 | fixed wing | "pop-up, turn, and dive" |
| 2 | fixed wing | "pop-up, turn, and dive" |
| 3 | fixed wing | "straight and level" |
| 4 | fixed wing | "constant g turn" |
| 5 | fixed wing | "jink" |
| 6 | fixed wing | "pop-up, turn, and dive" |
| 7 | fixed wing | "straight and level" |
| 8 | fixed wing | "constant g turn" |
| 9 | helicopter | "hover" |
| 10 | helicopter | "hover" |
| 11 | helicopter | "hover" |
| 12 | helicopter | "hover" |
| 13 | helicopter | "straight and level" |
| 14 | helicopter | "constant g turn" |
| 15 | helicopter | "pop-up and shallow dive" |
| 16 | fixed wing | "turn and dive" |

The flightpaths are depicted in figures 1 through 96. For each flightpath, there are two three dimensional views and time histories for each of the nine state variables and the attitude angles. In the three dimensional pictures, the x, y, and z axes are denoted by "east", "north", and "up" respectively, and the origin of the coordinate system lies at the center of the small rectangular box depicted in the ground plane. The small arrows indicate the direction of aircraft motion. Due to scaling problems in the case of the hovering helicopters, we have presented a close-up high angle view in which the solid circles represent the location of the "center" of the helicopter at one second intervals. This was done to give the reader a feel for the extent of both vertical and lateral motion of the helicopters when hovering.

The resolution of the data is one centimeter for the state variables and one tenth of a milliradian for the attitude angles. This causes some time histories to appear as "step functions" (see e.g., figure 53). Also, the restriction that the values of the FORTRAN ATAN2 function lie in the interval $(-\pi,\pi)$ gives rise to the apparent instantaneous 360 degree "jump" that appears in some of the time histories of the attitude angles (see e.g., figure 6).

As data from future field tests becomes available, this library of flightpaths will be updated and expanded to include new aircraft and new maneuvers.

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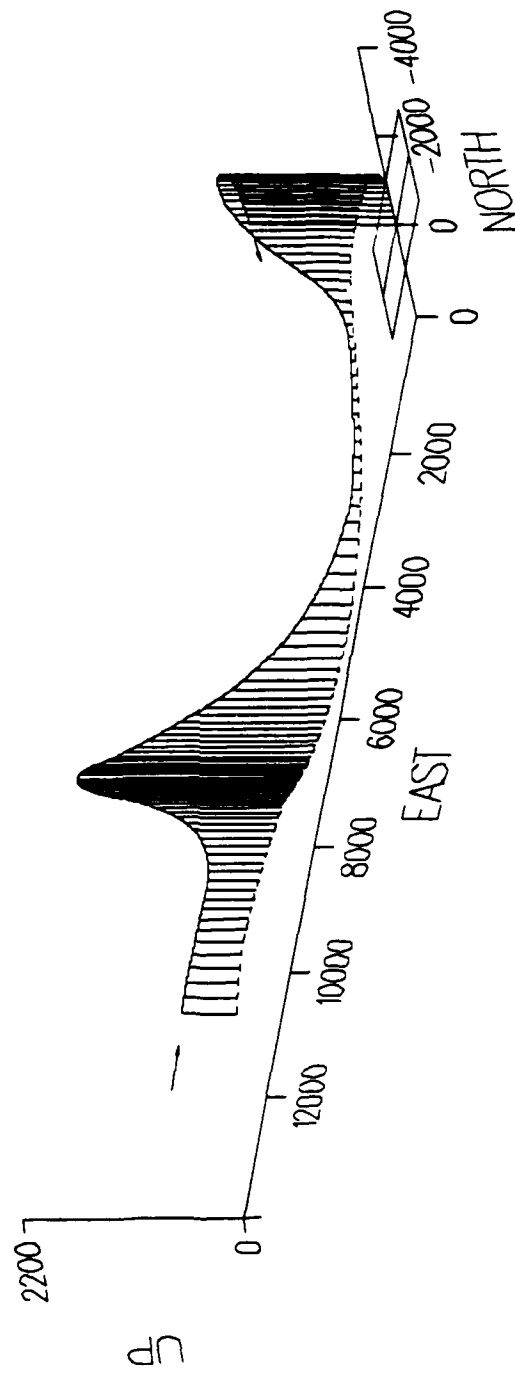
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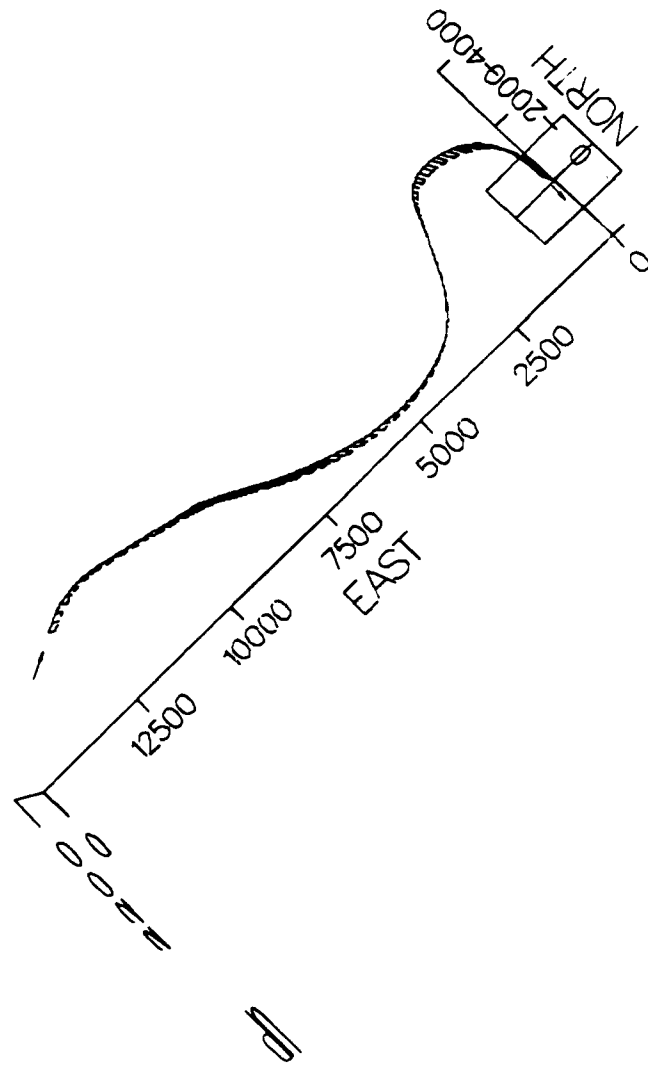
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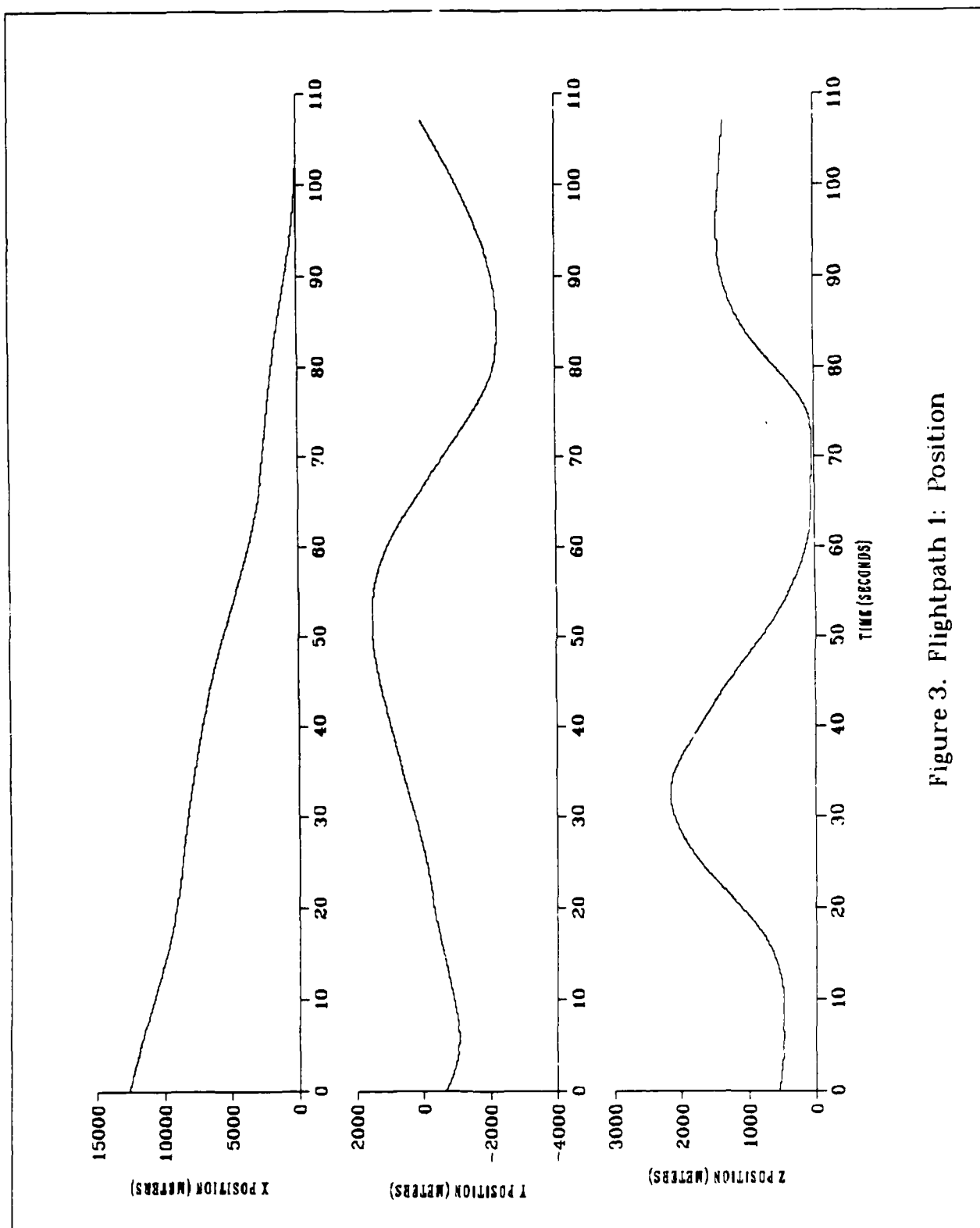
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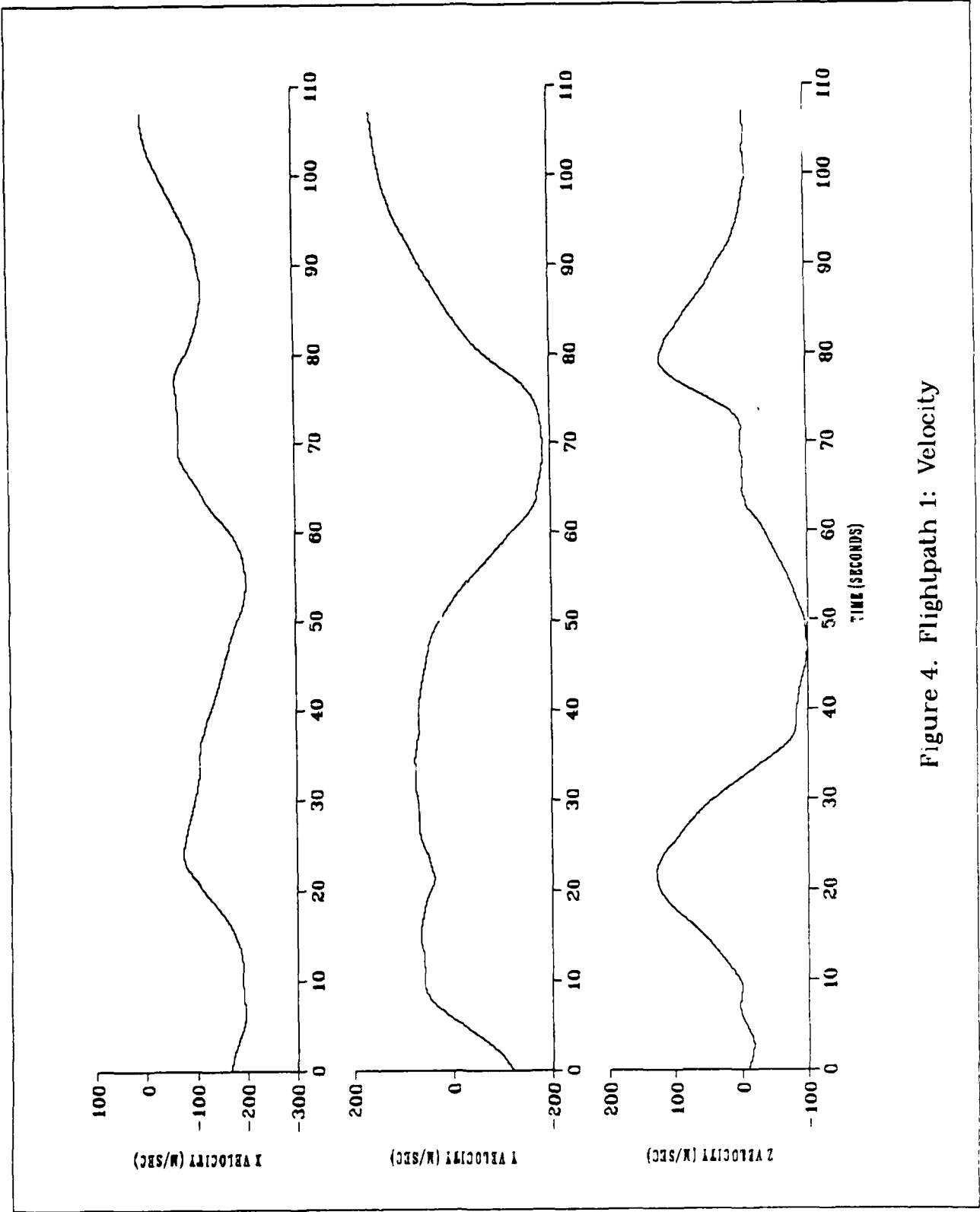
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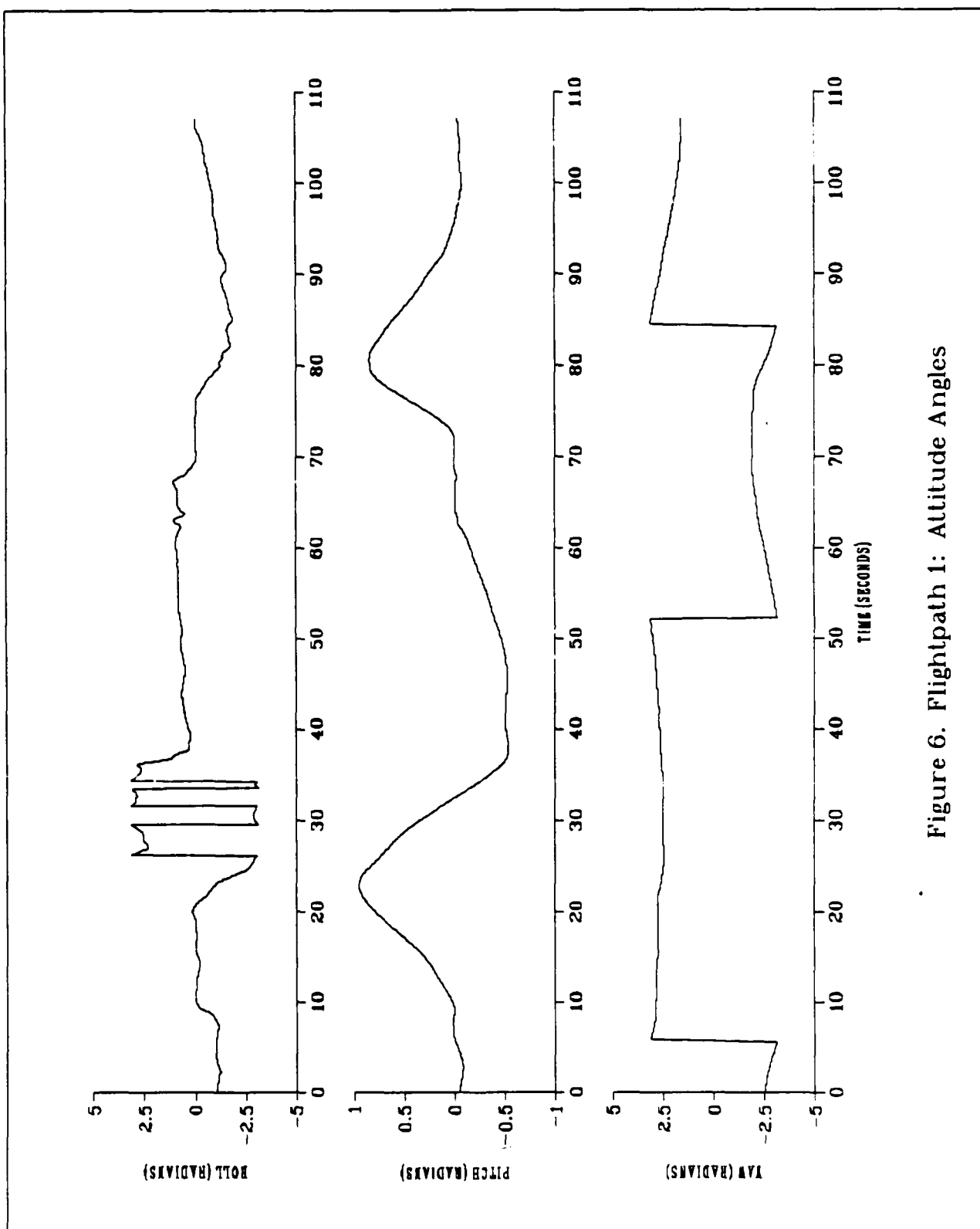
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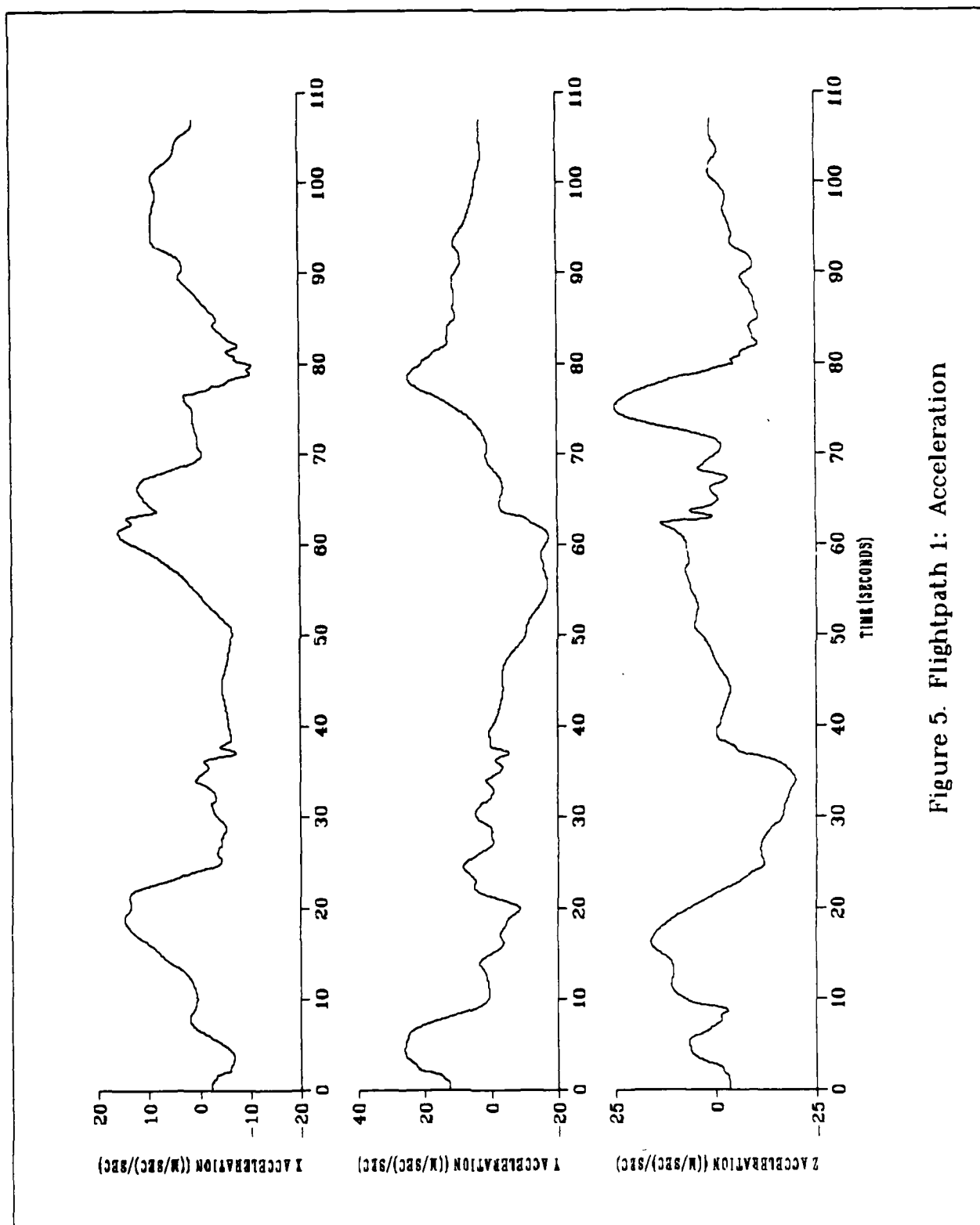
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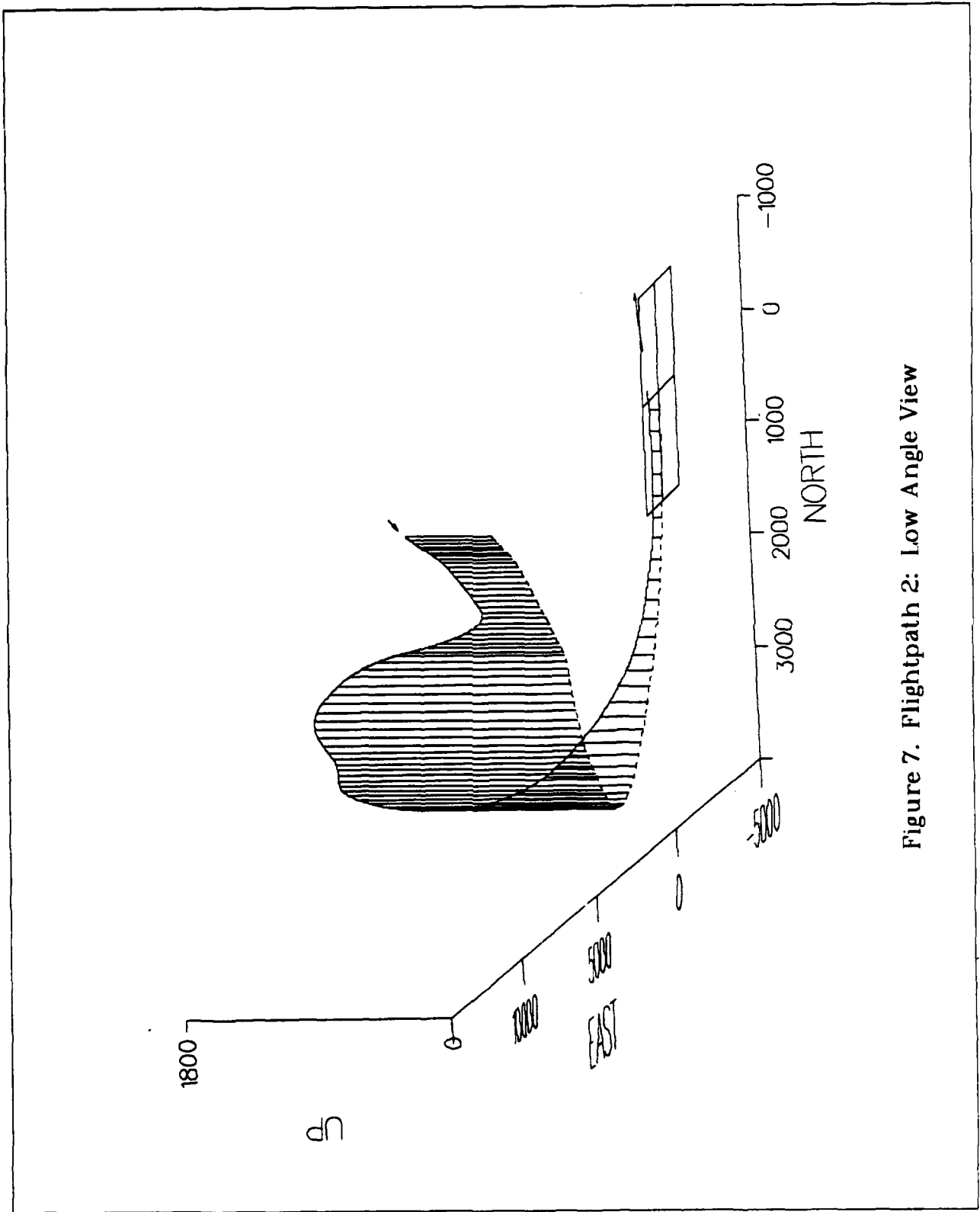Figure 6. Flightpath 1: Attitude Angles
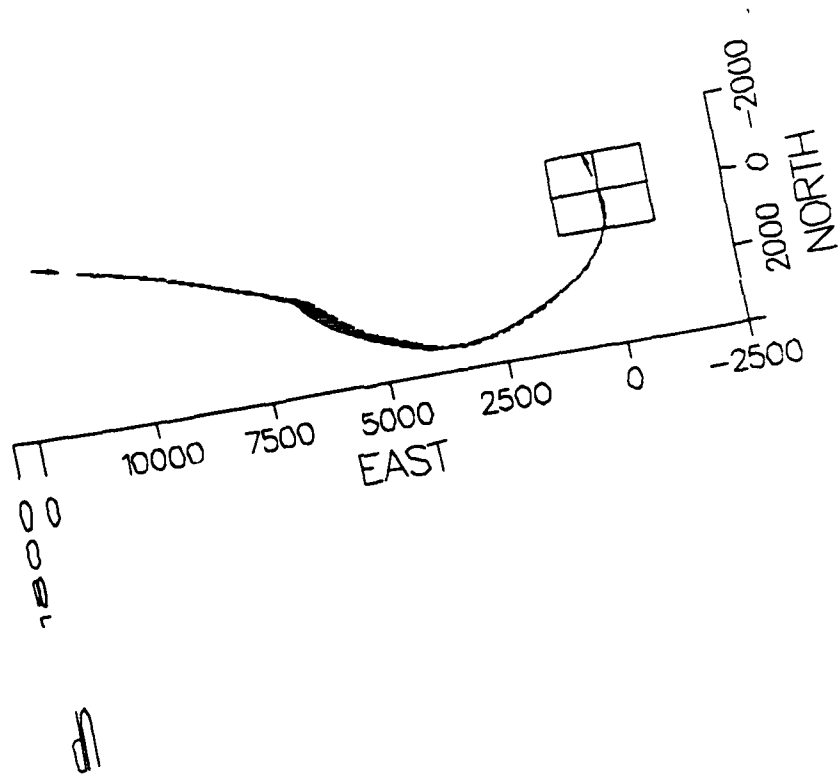
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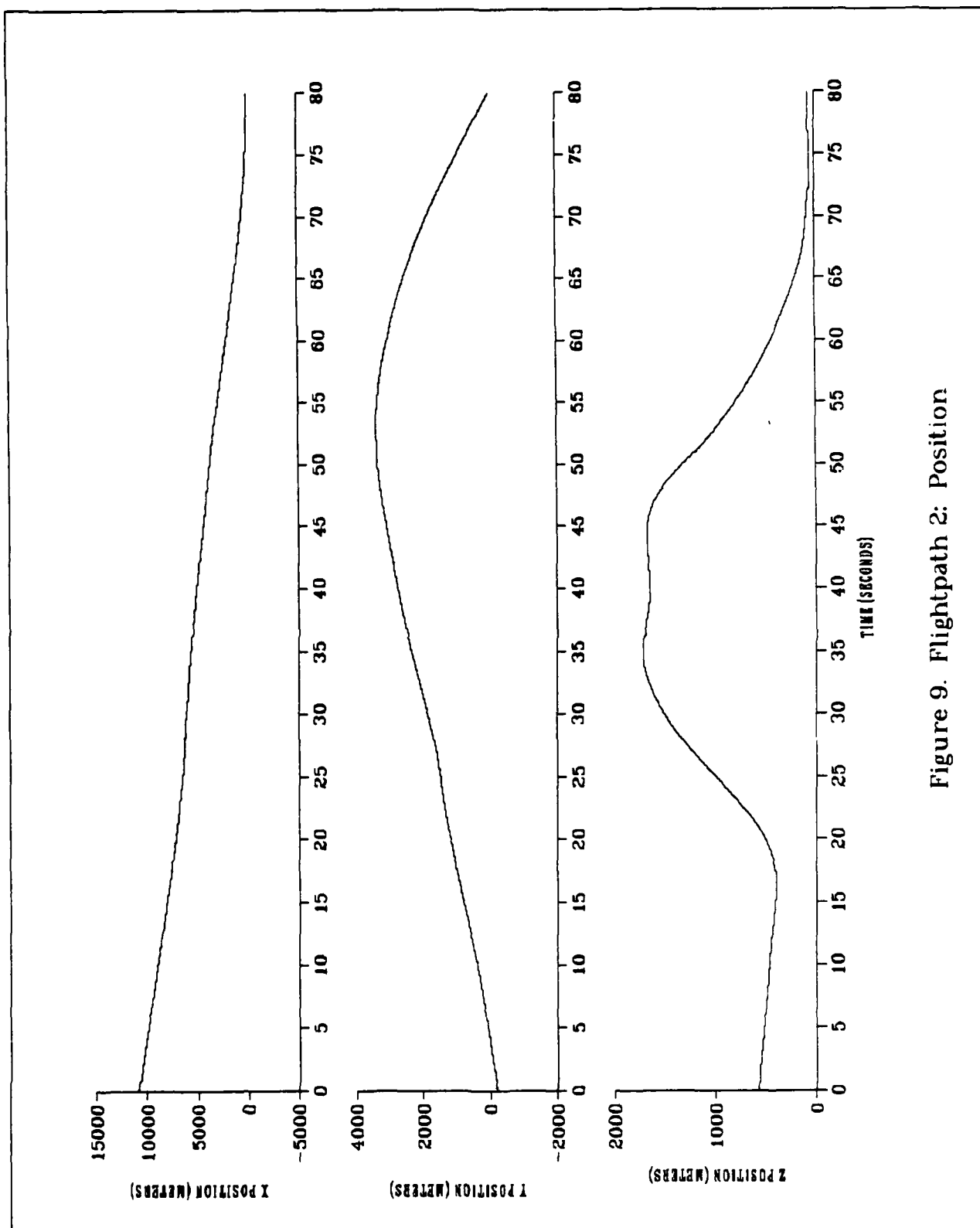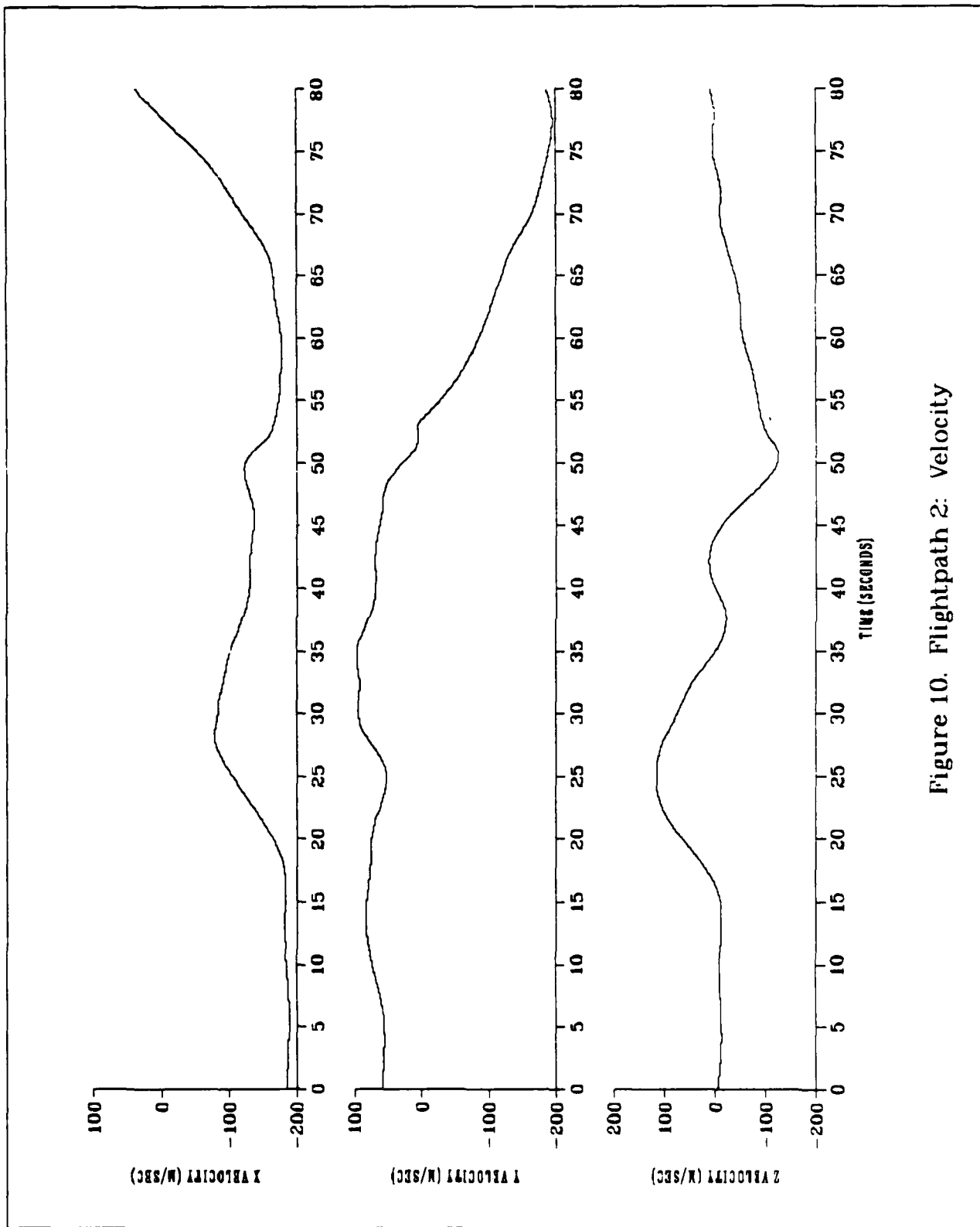
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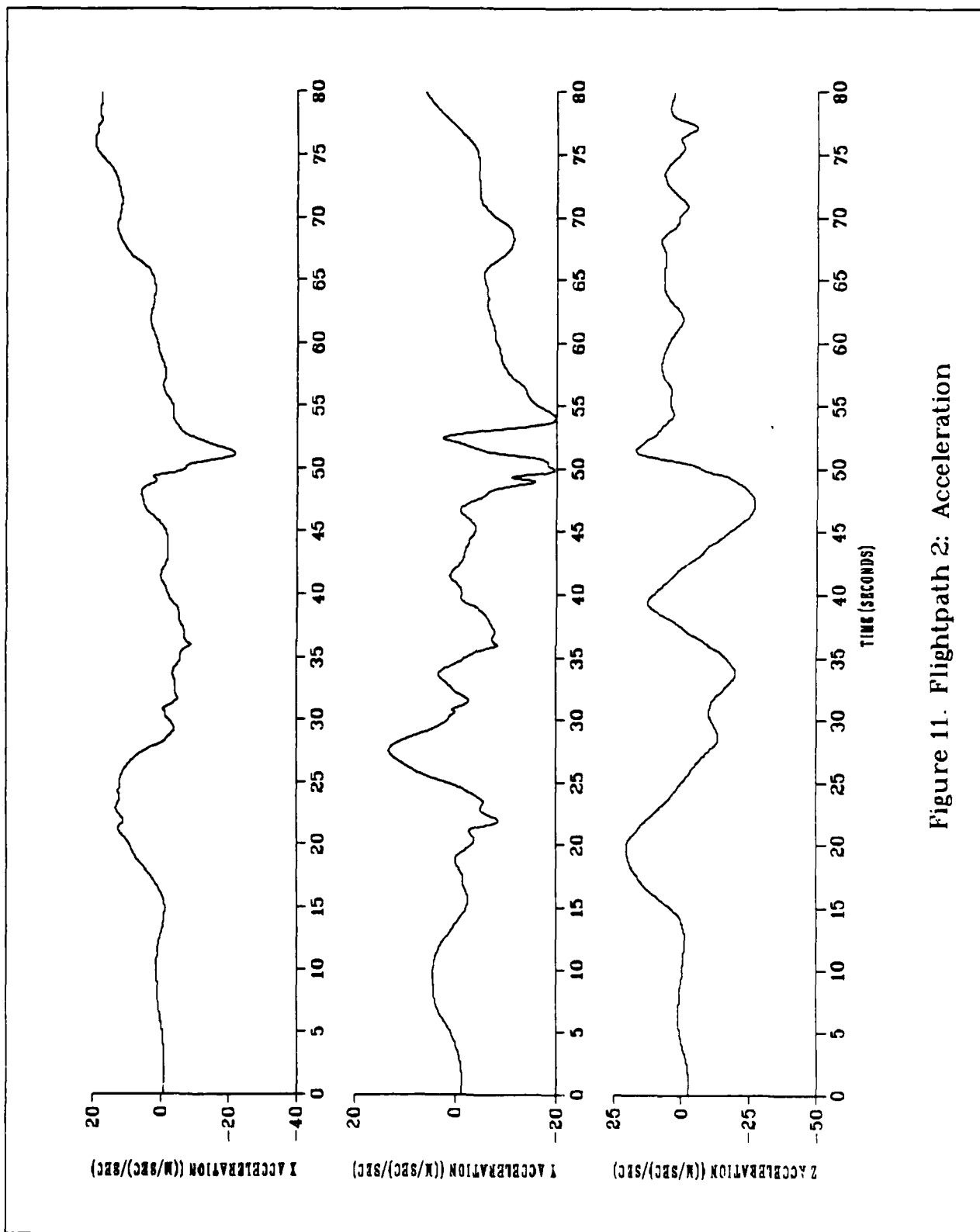
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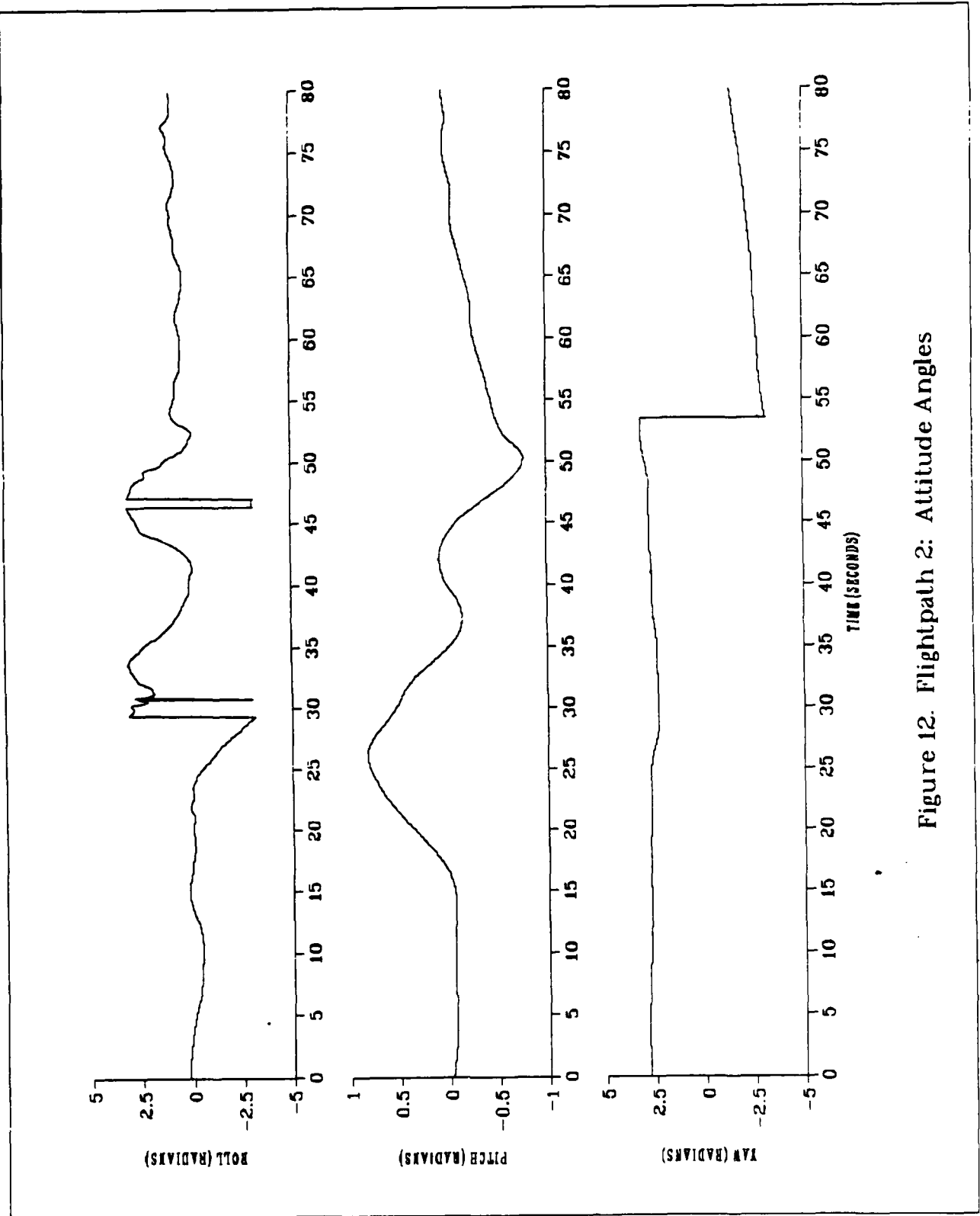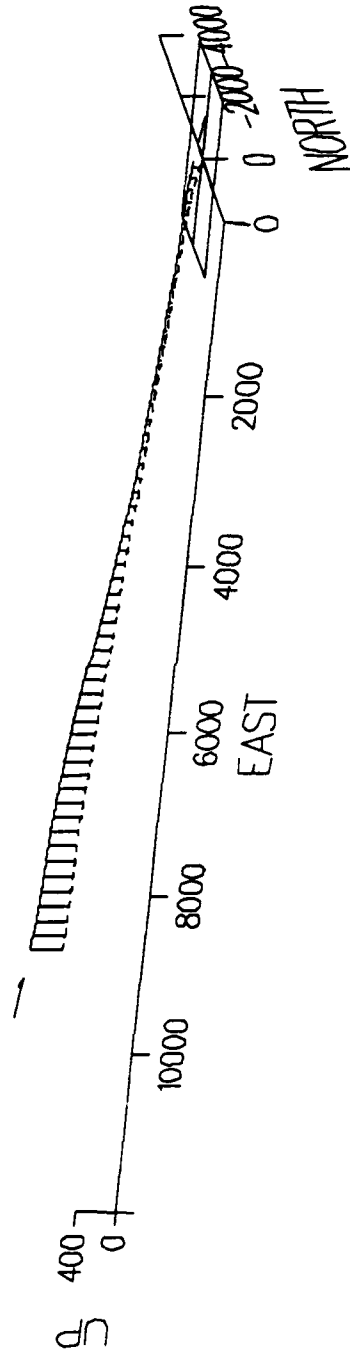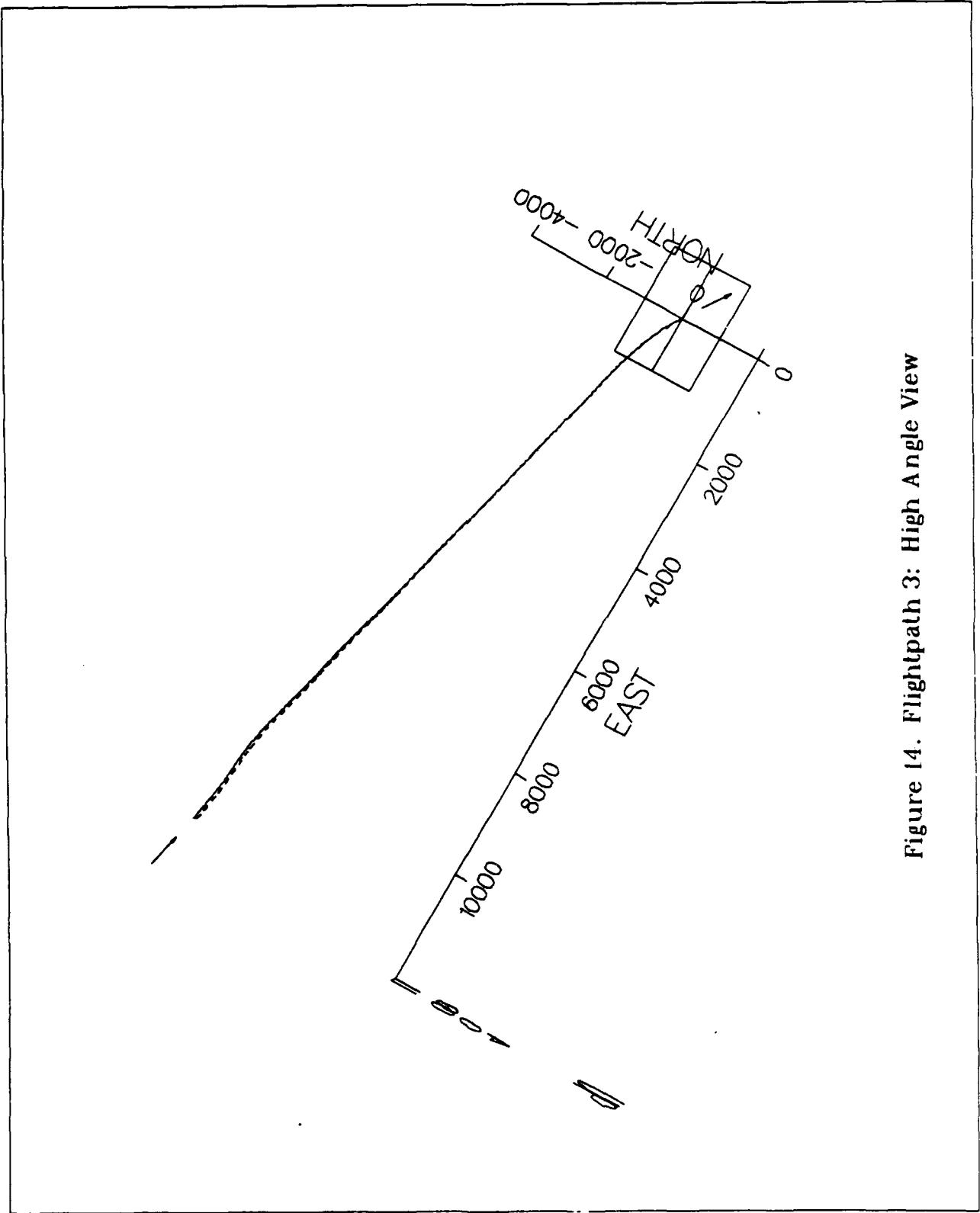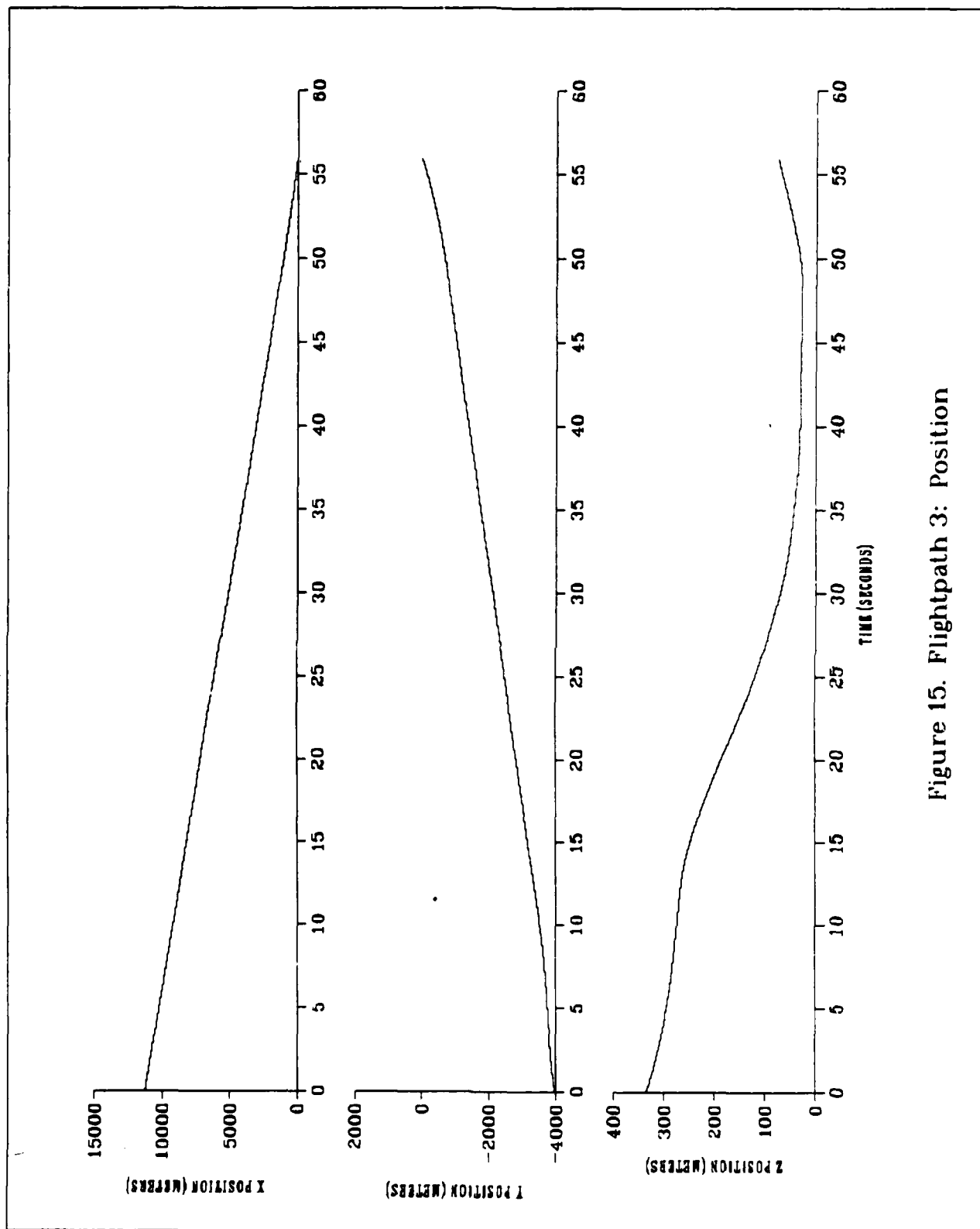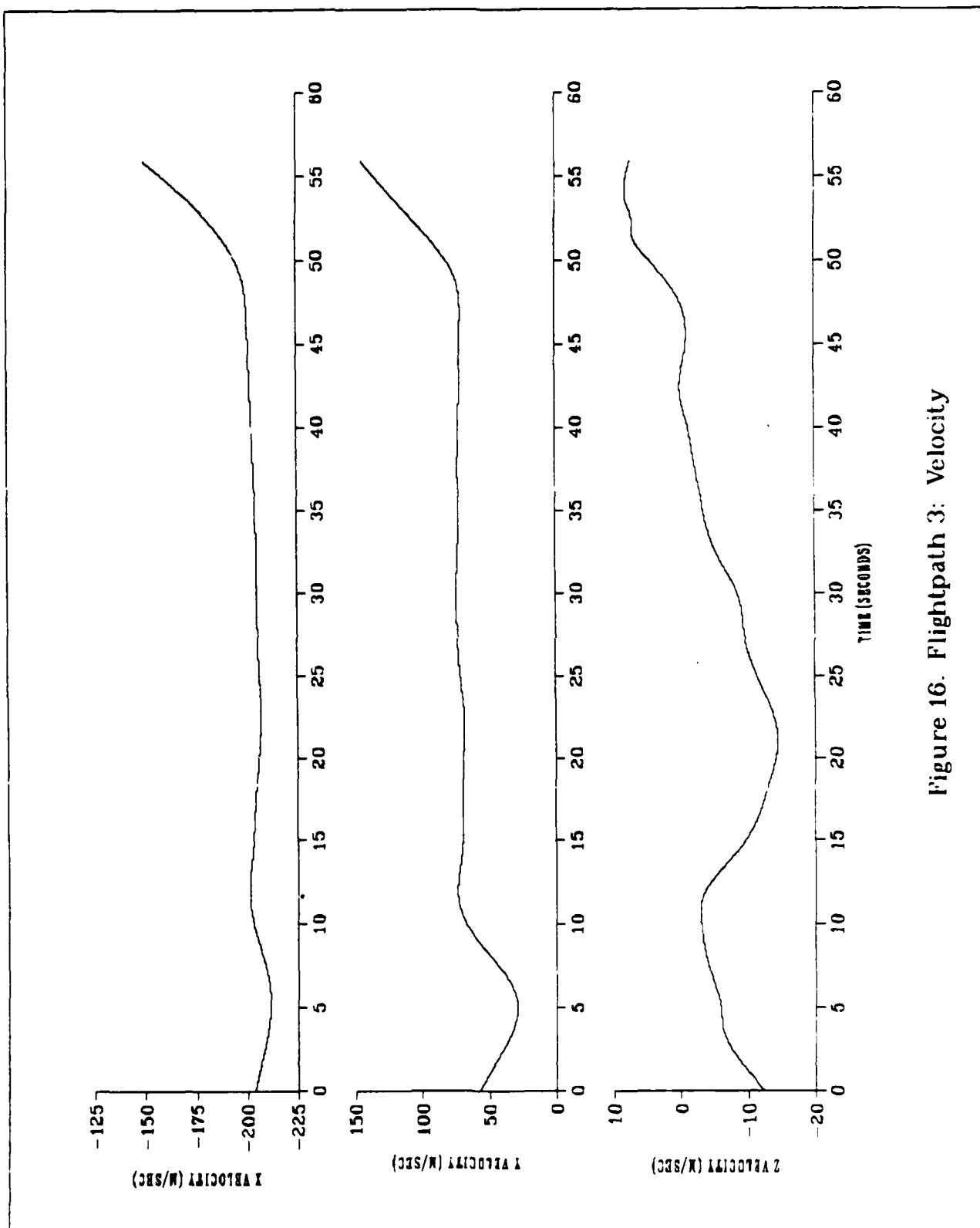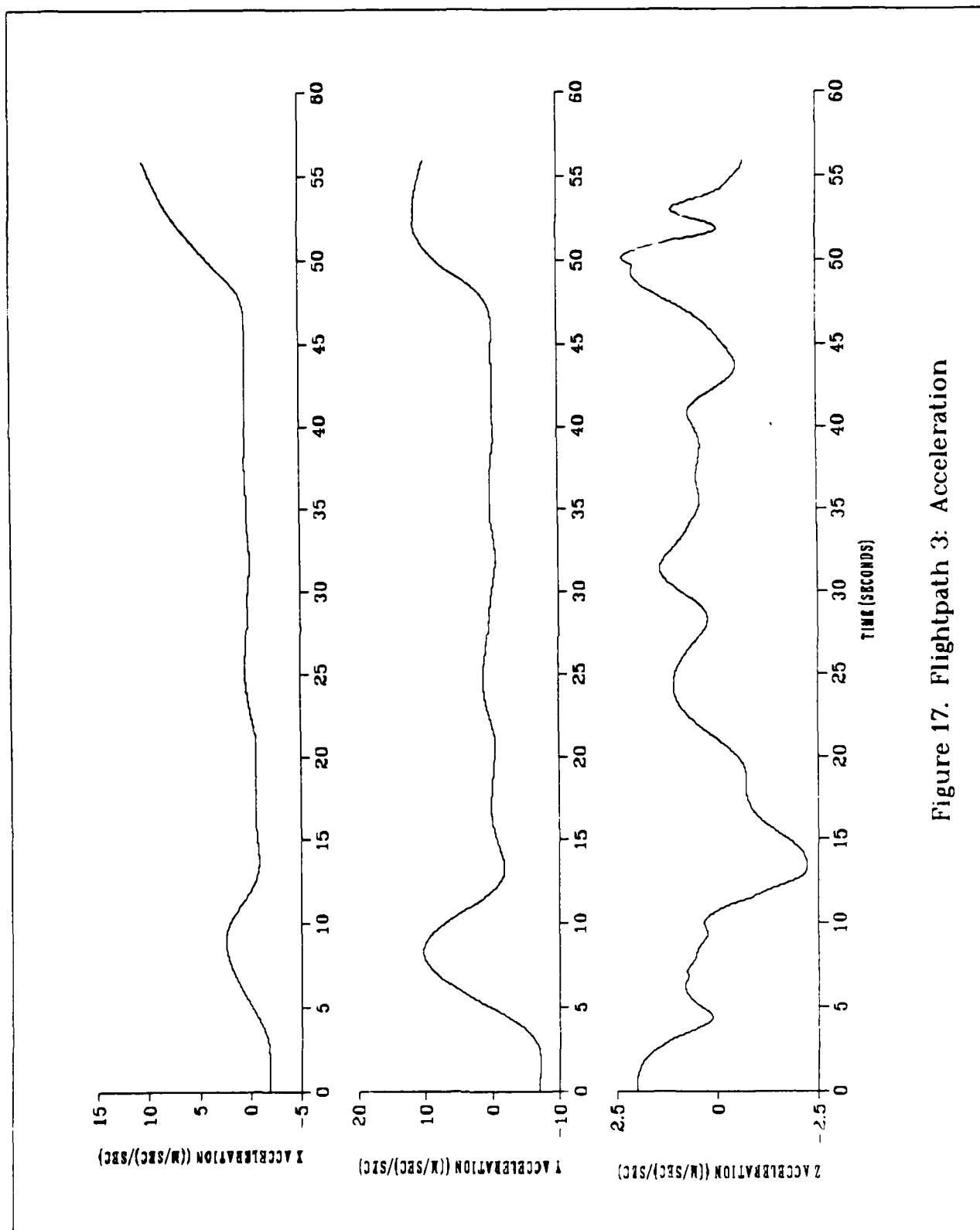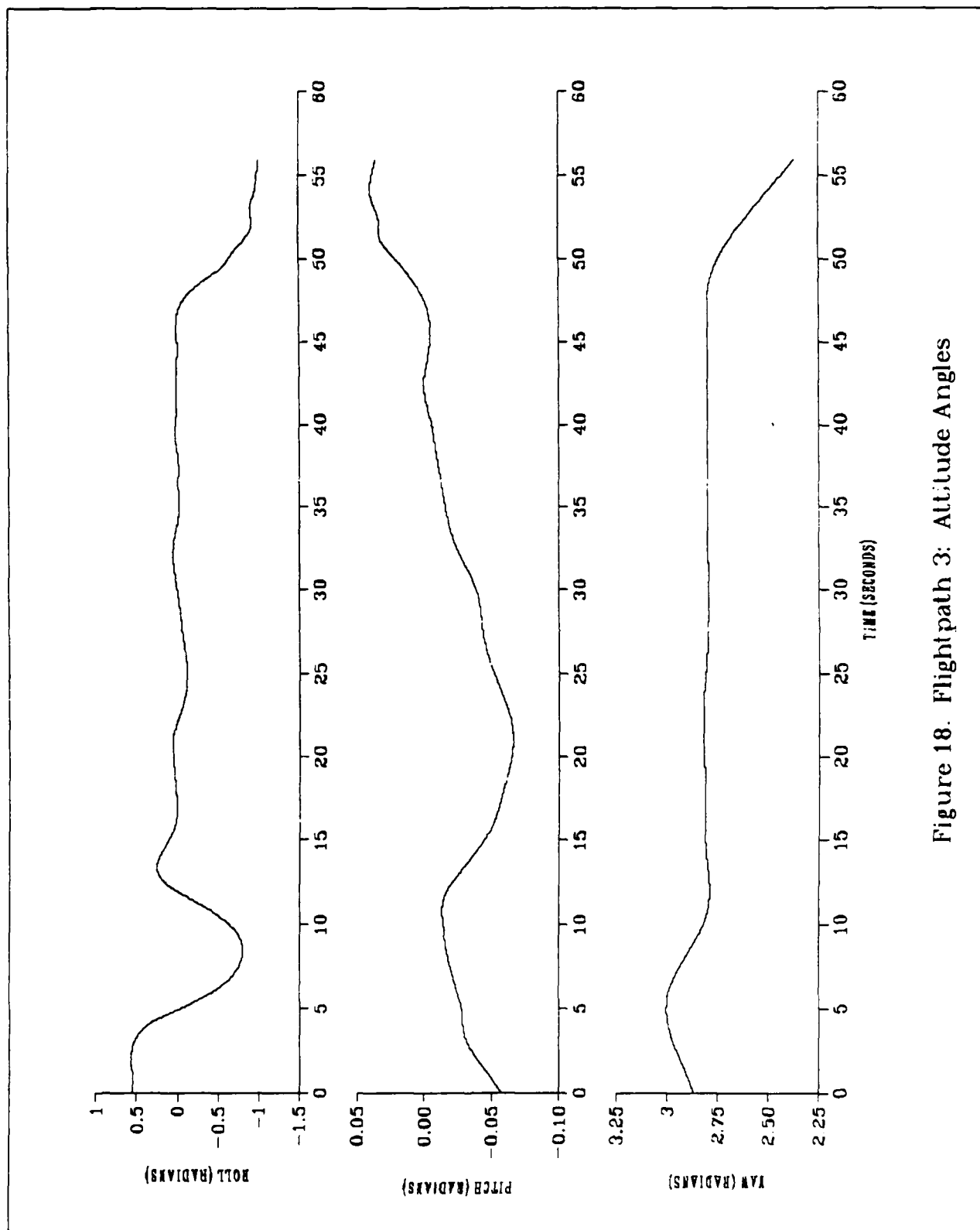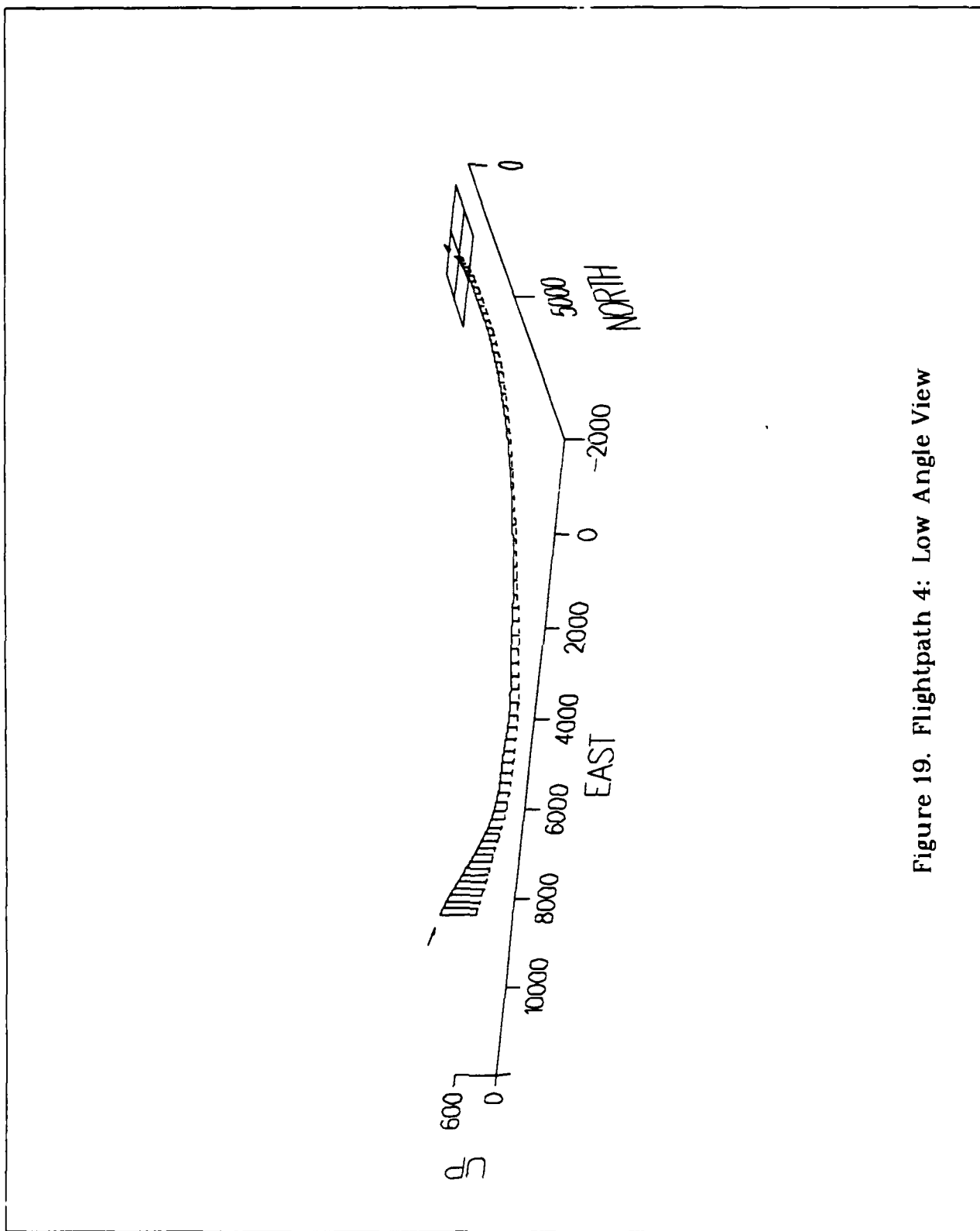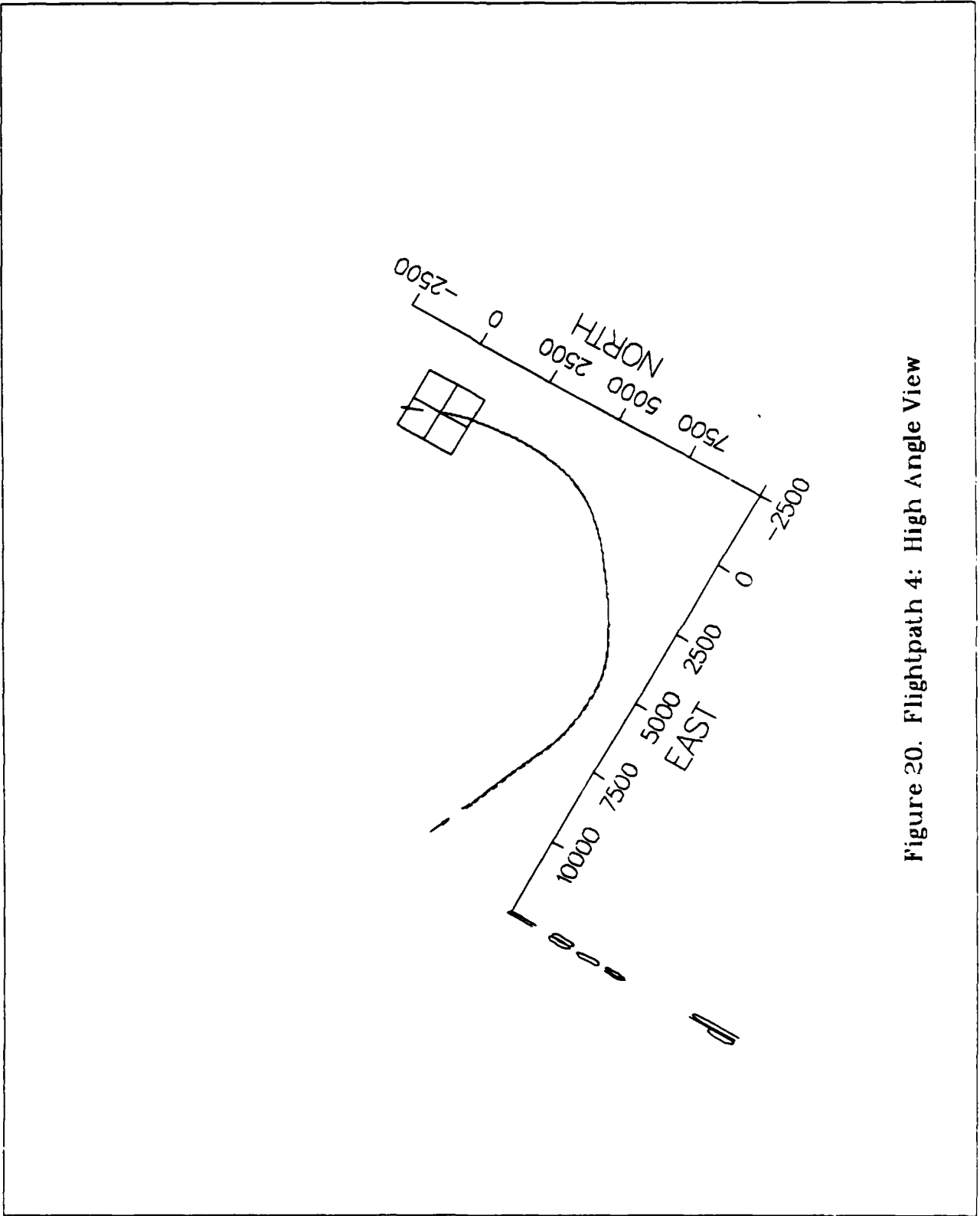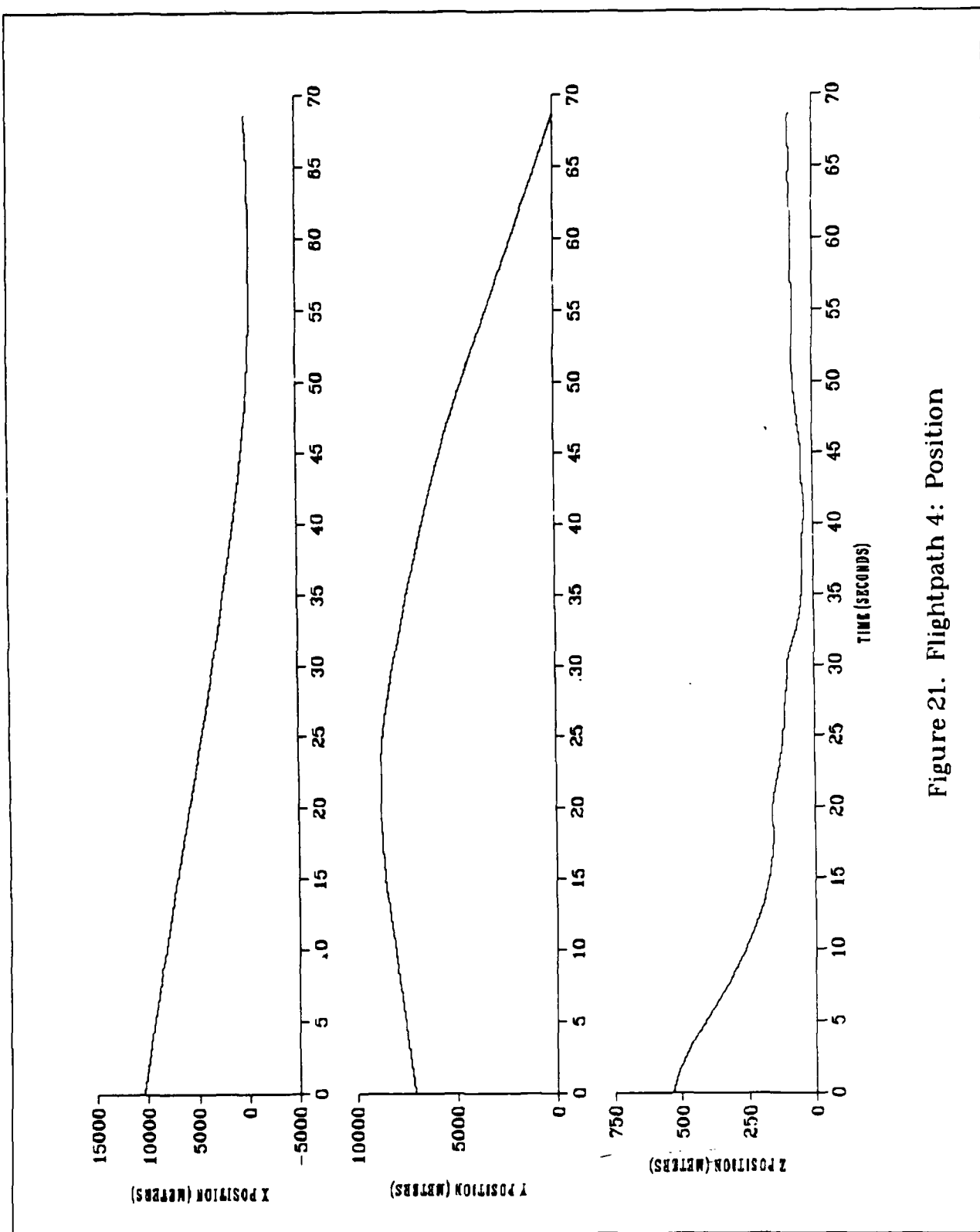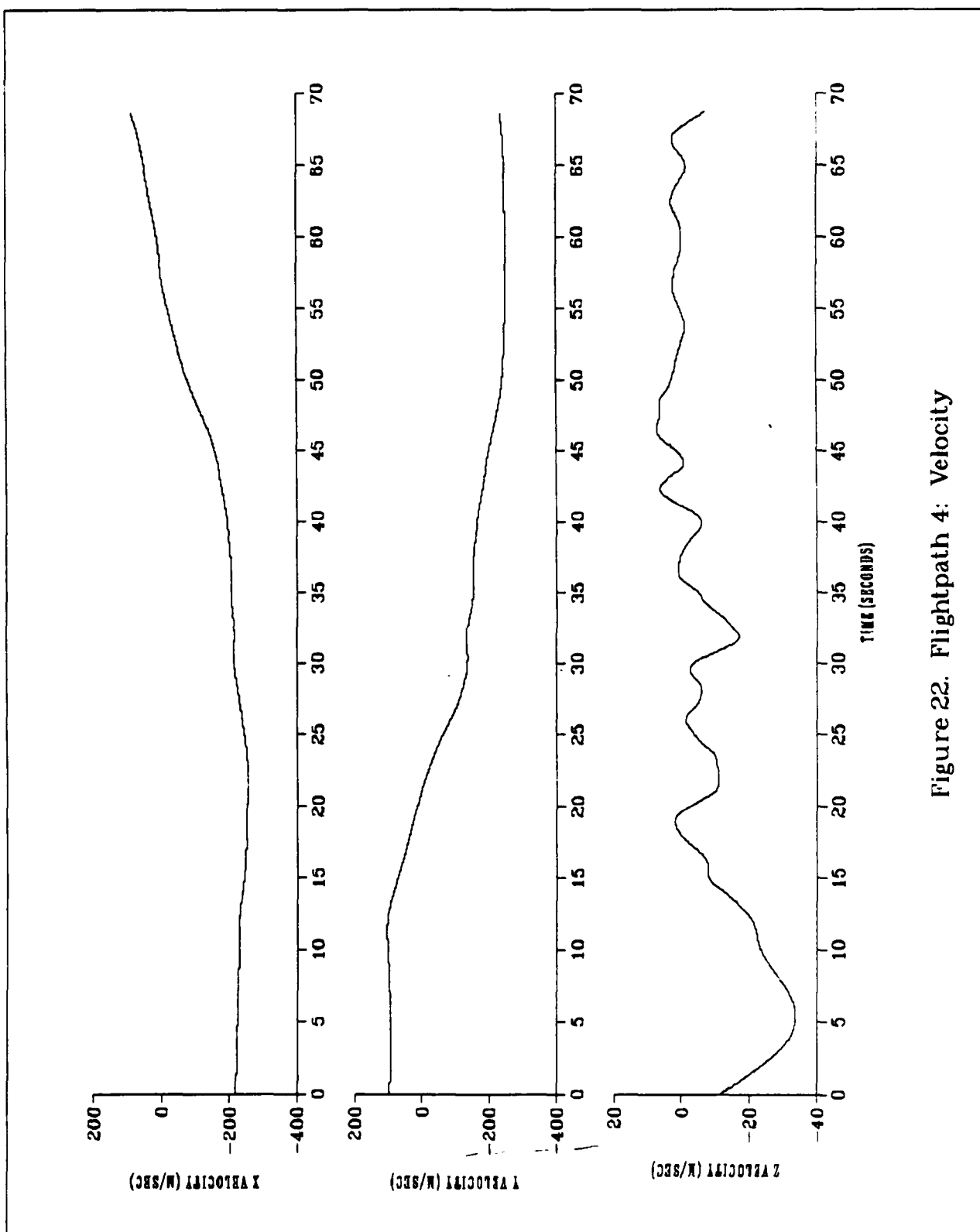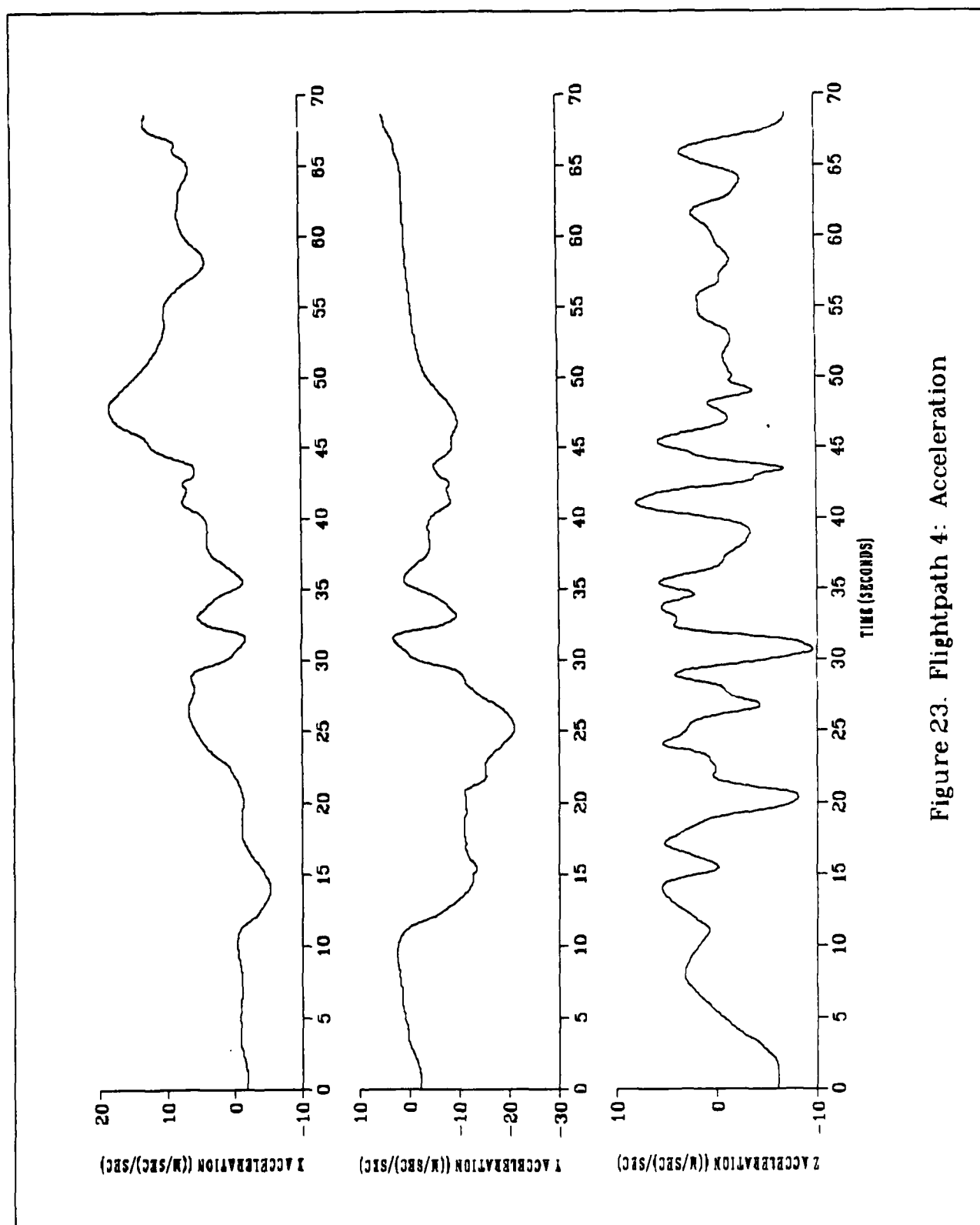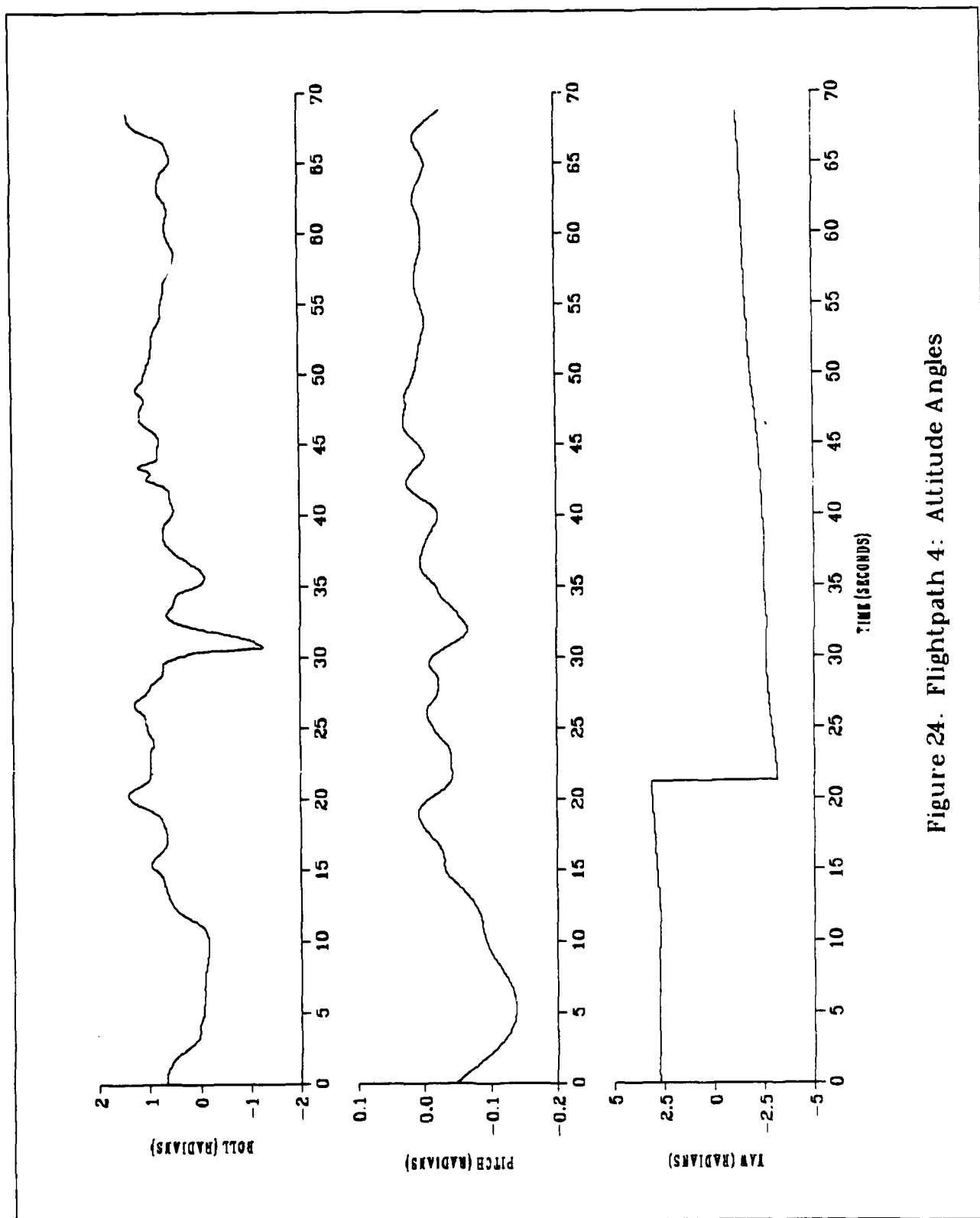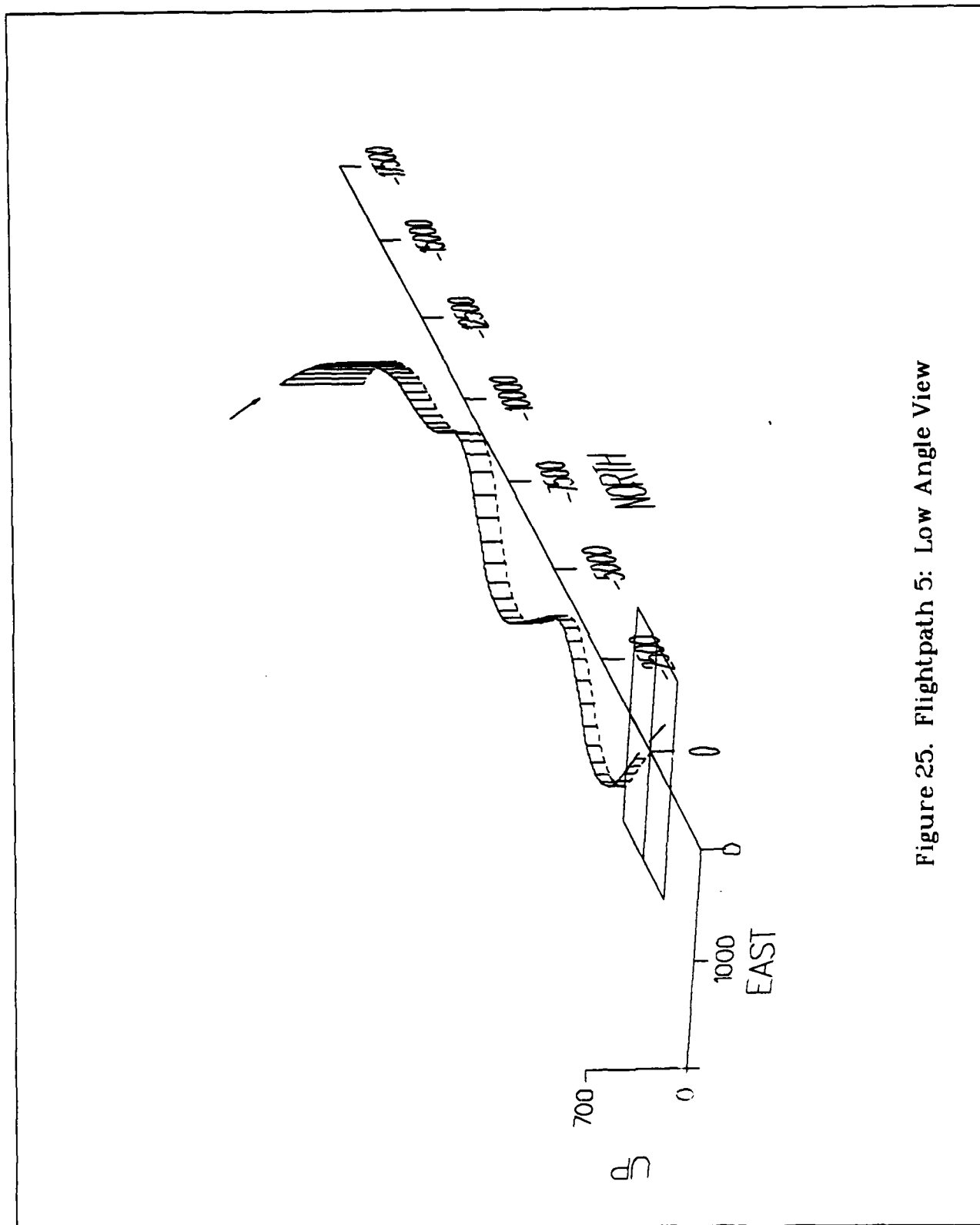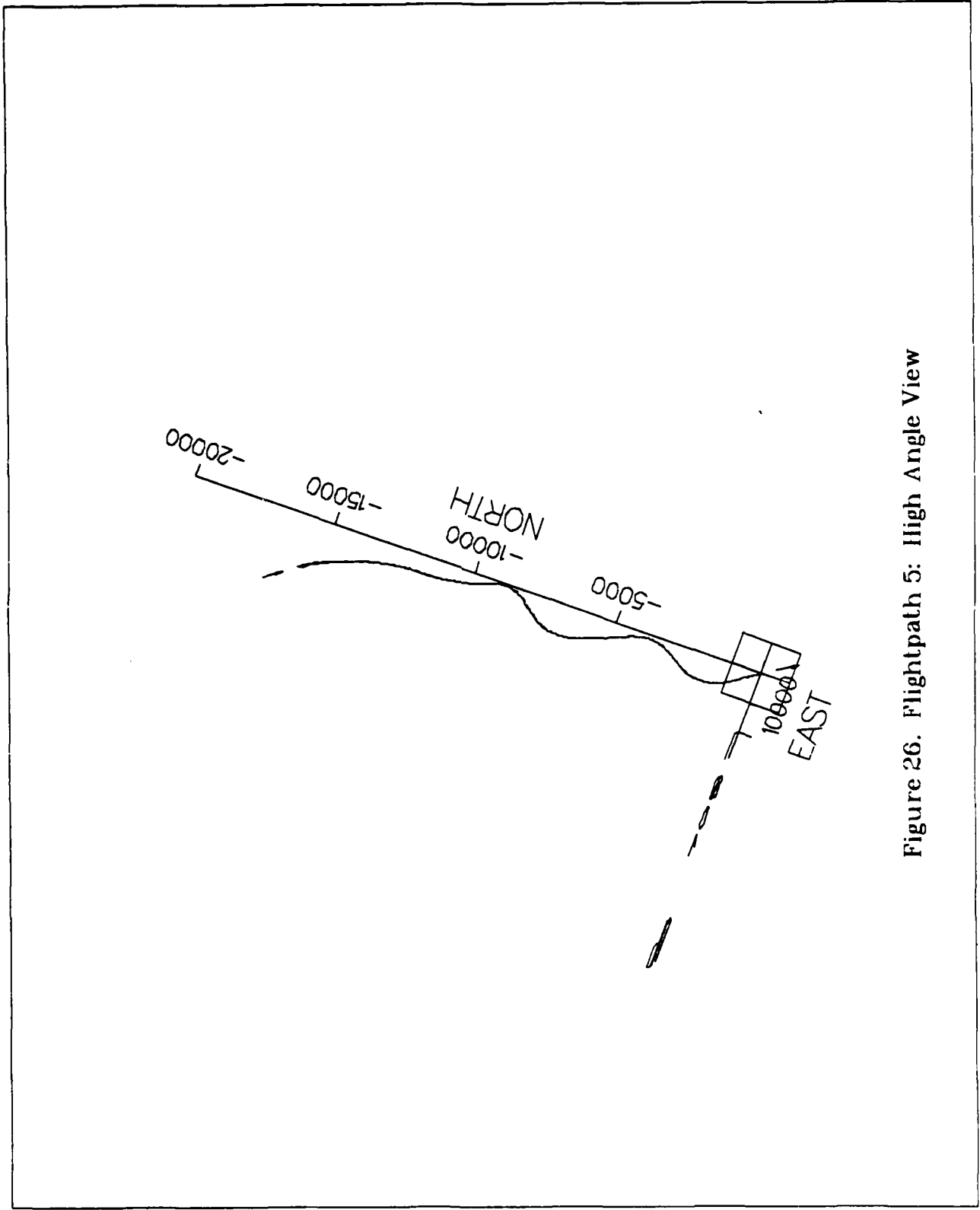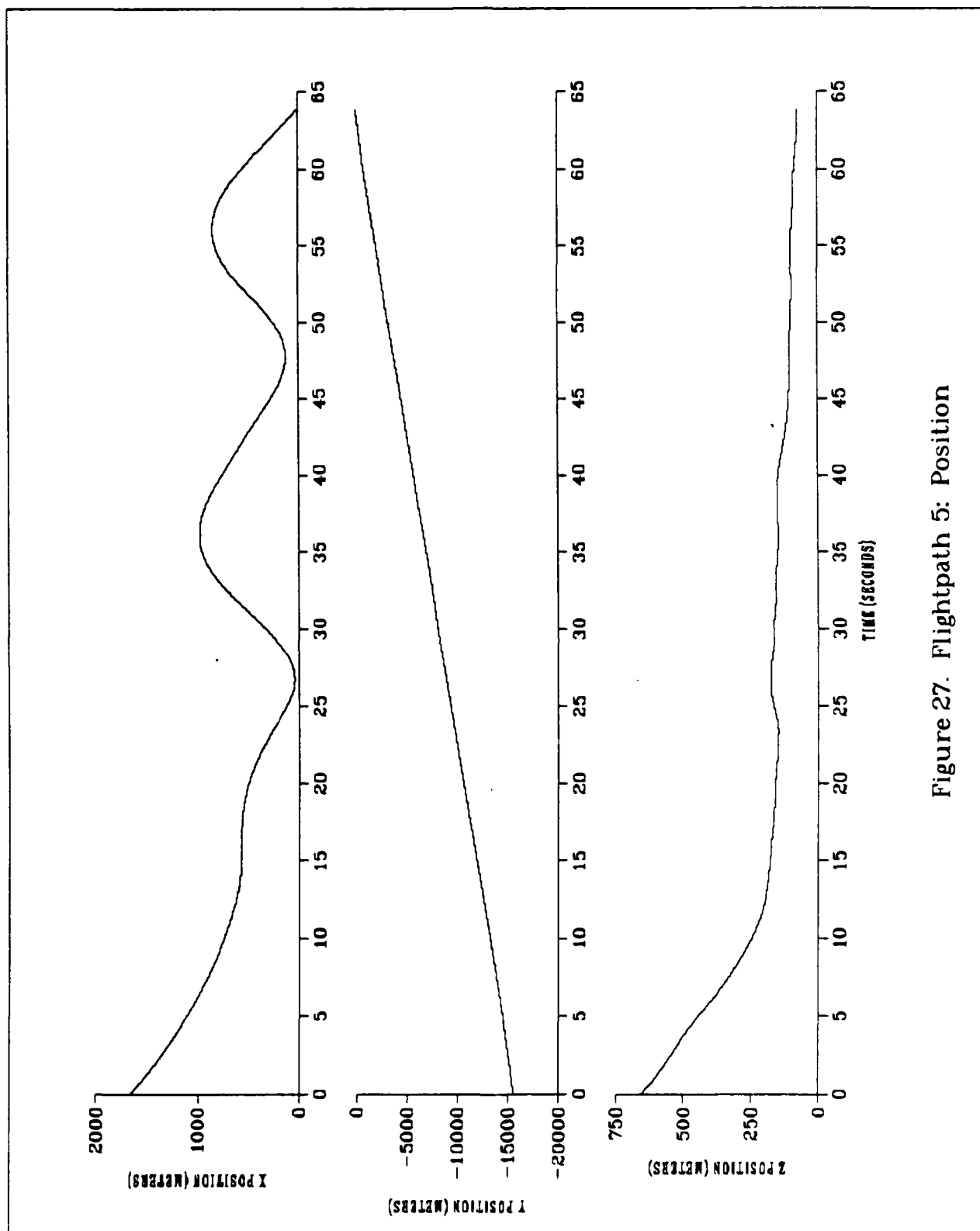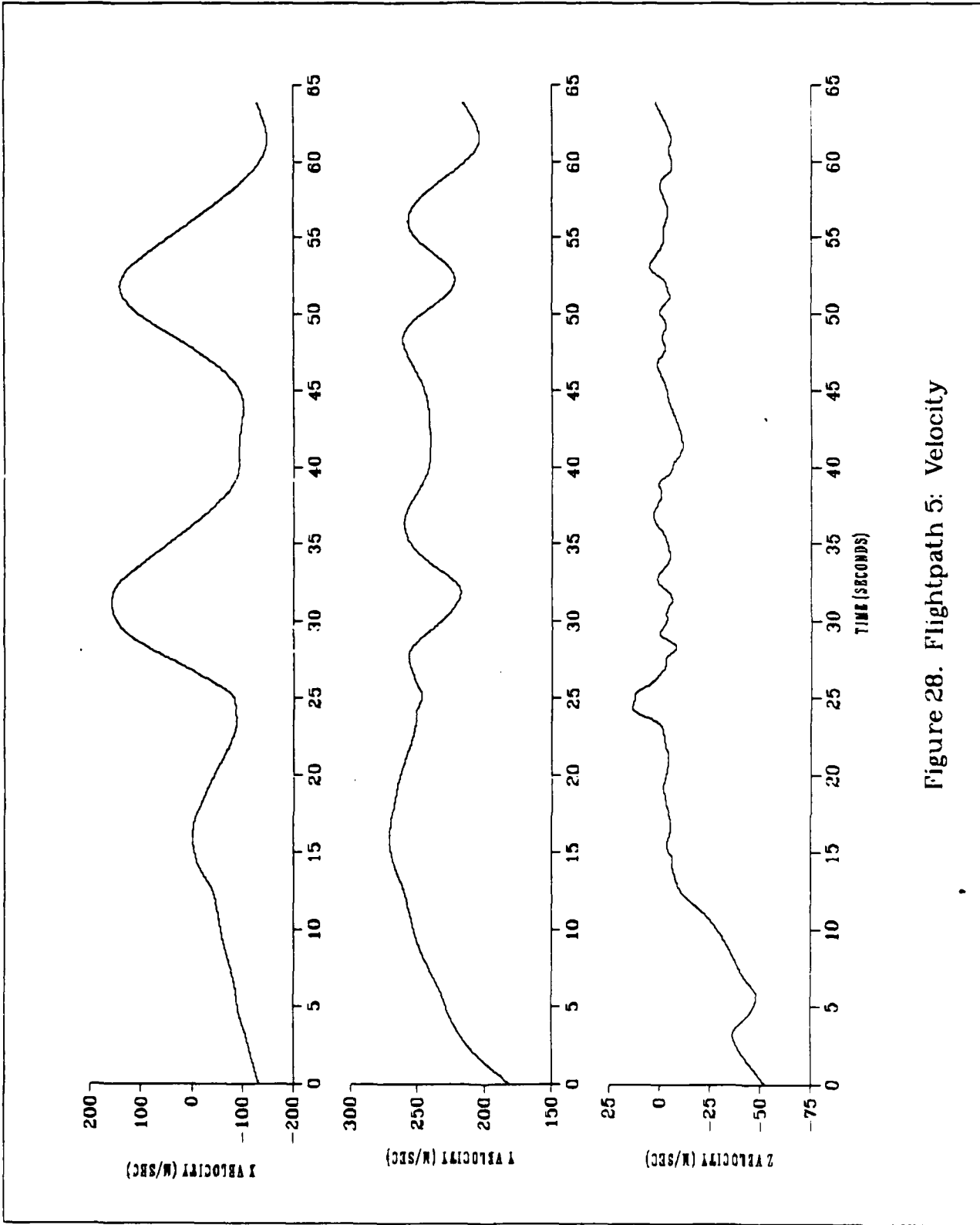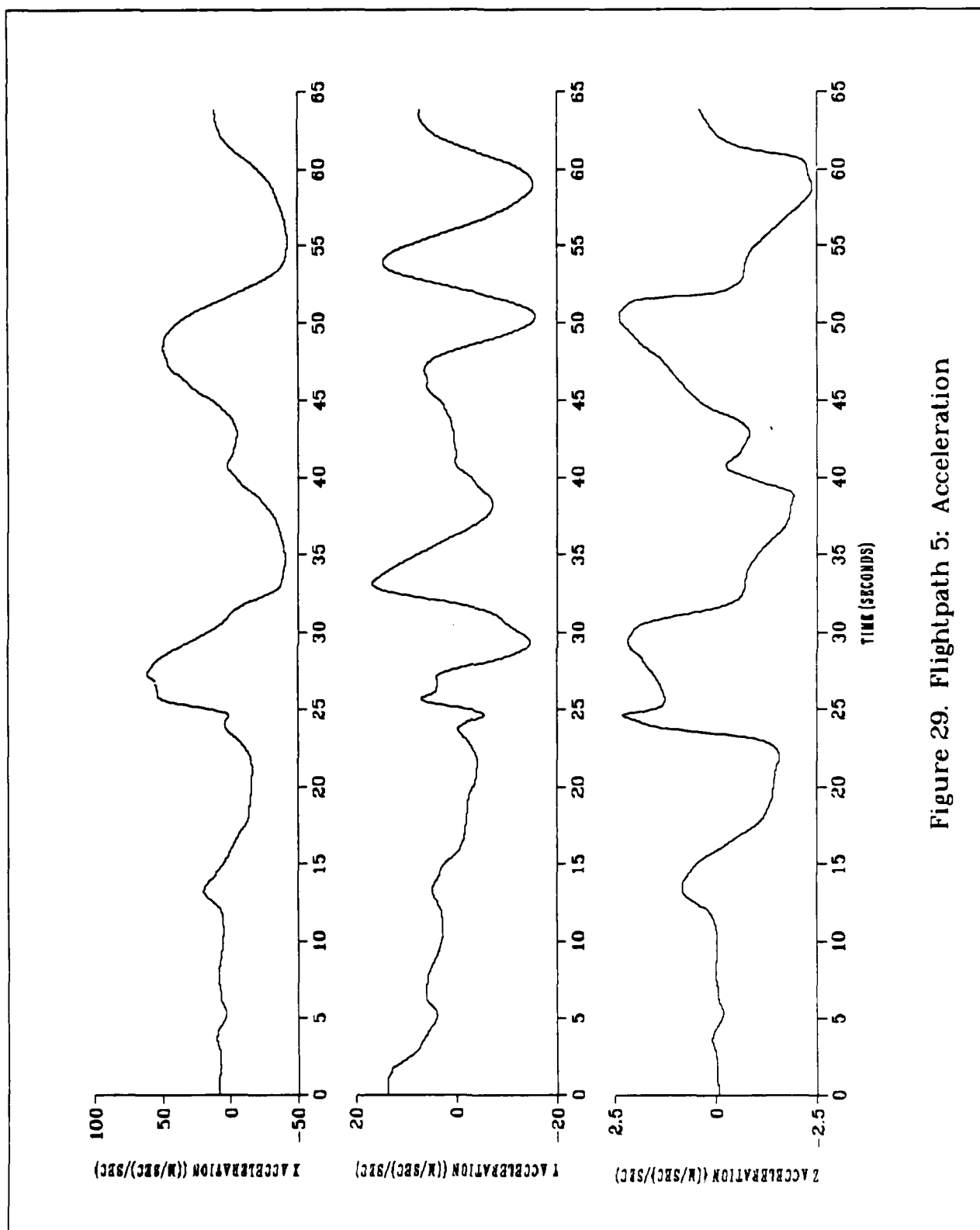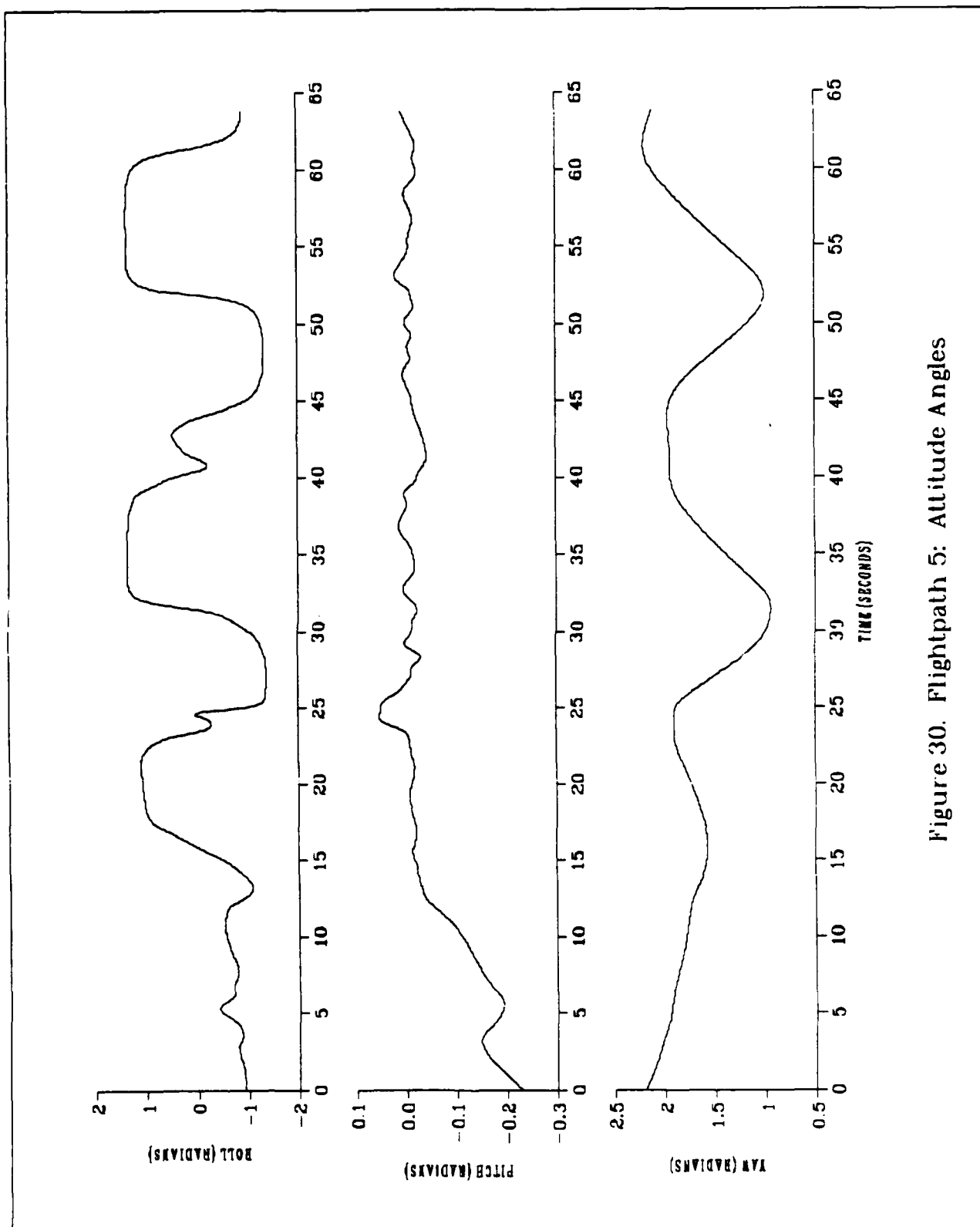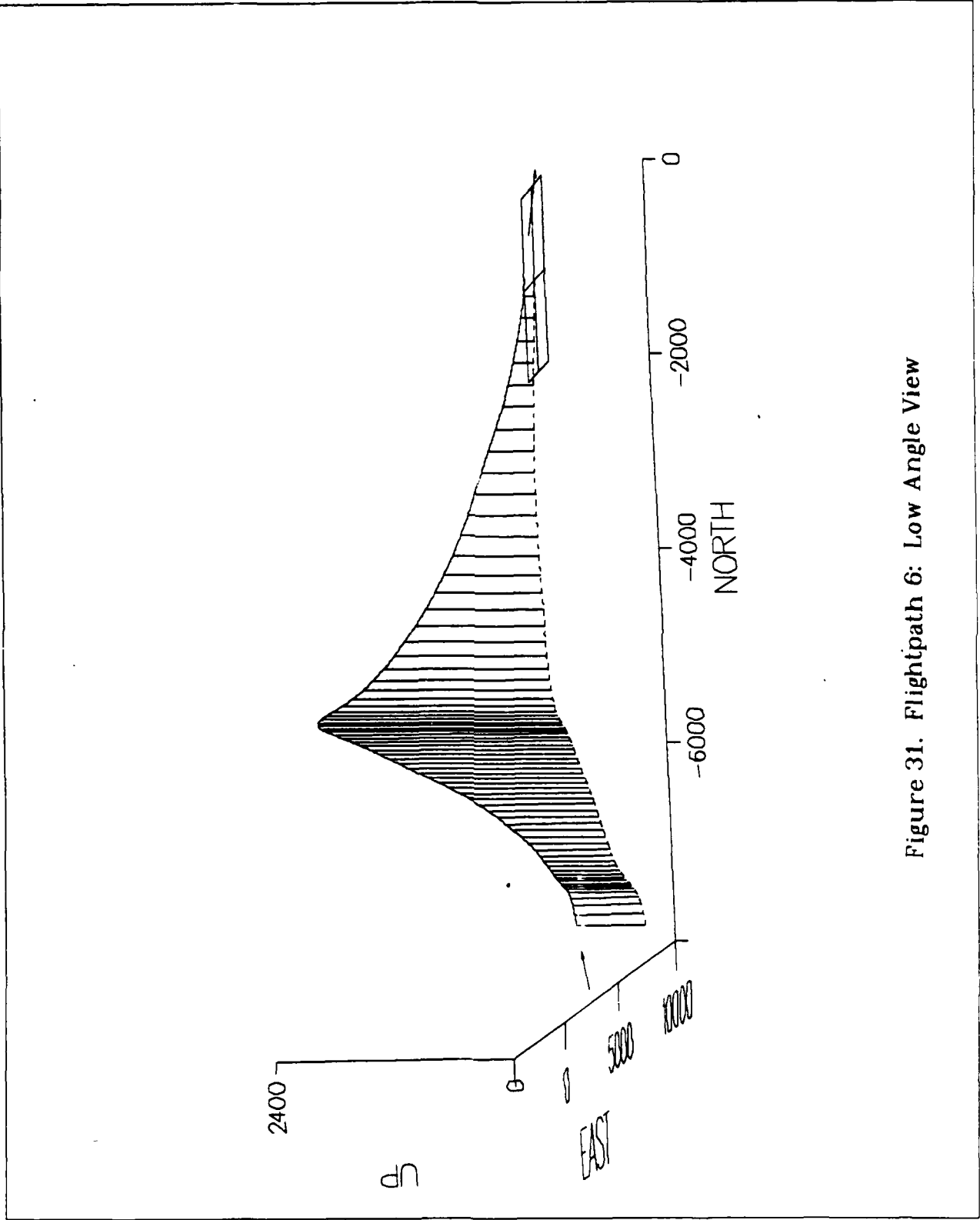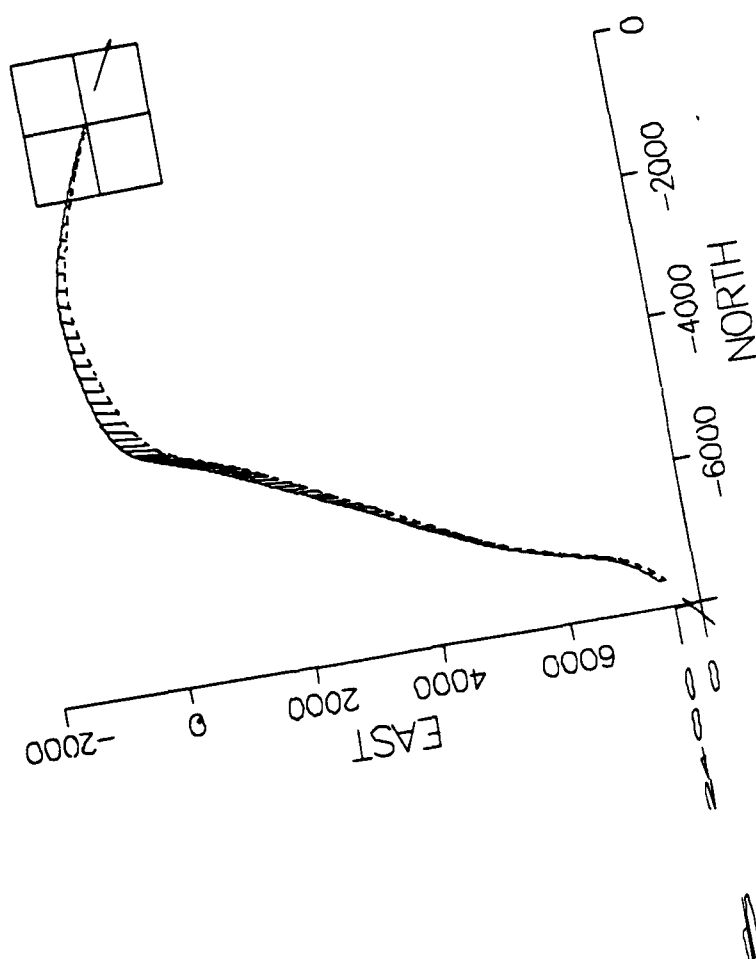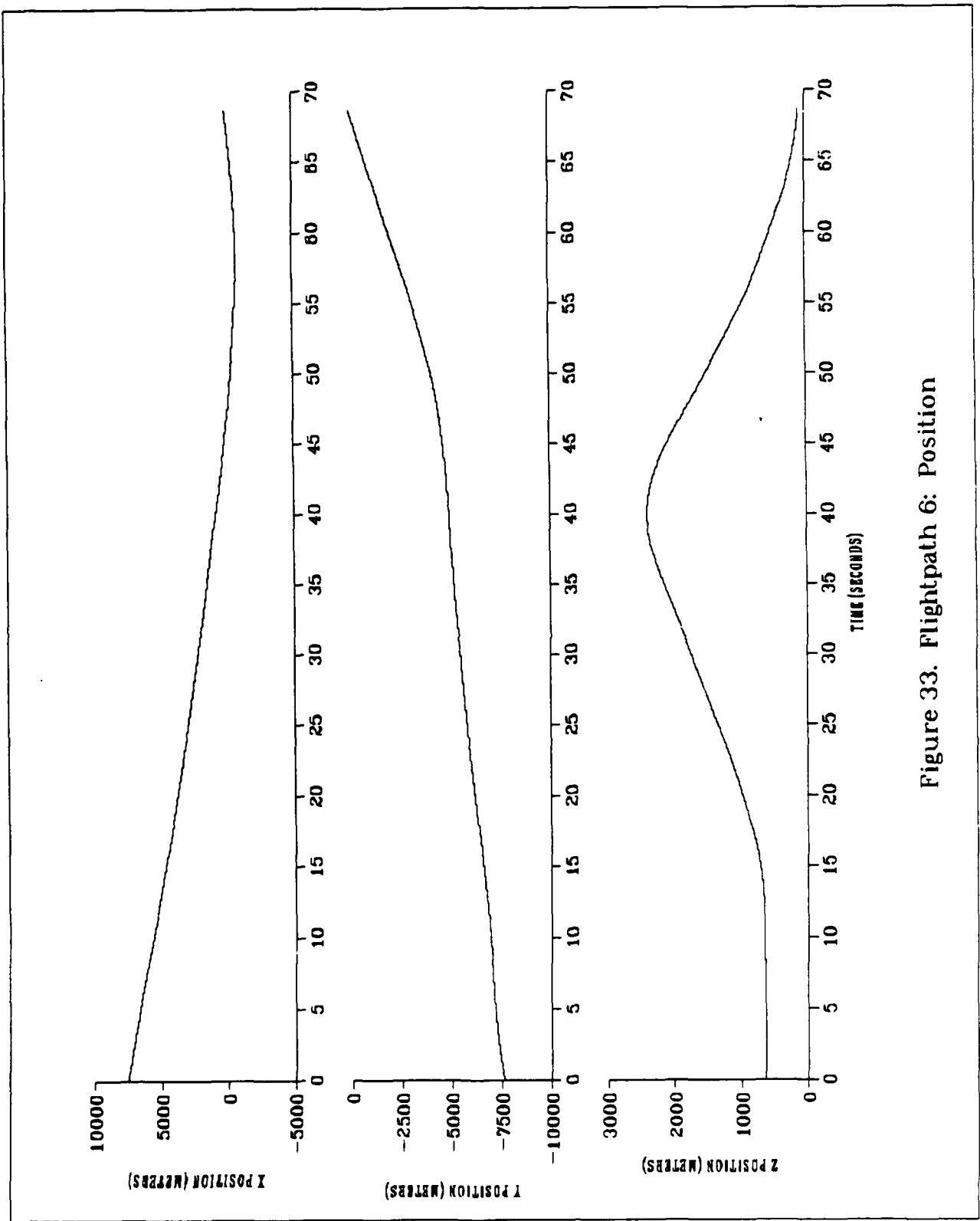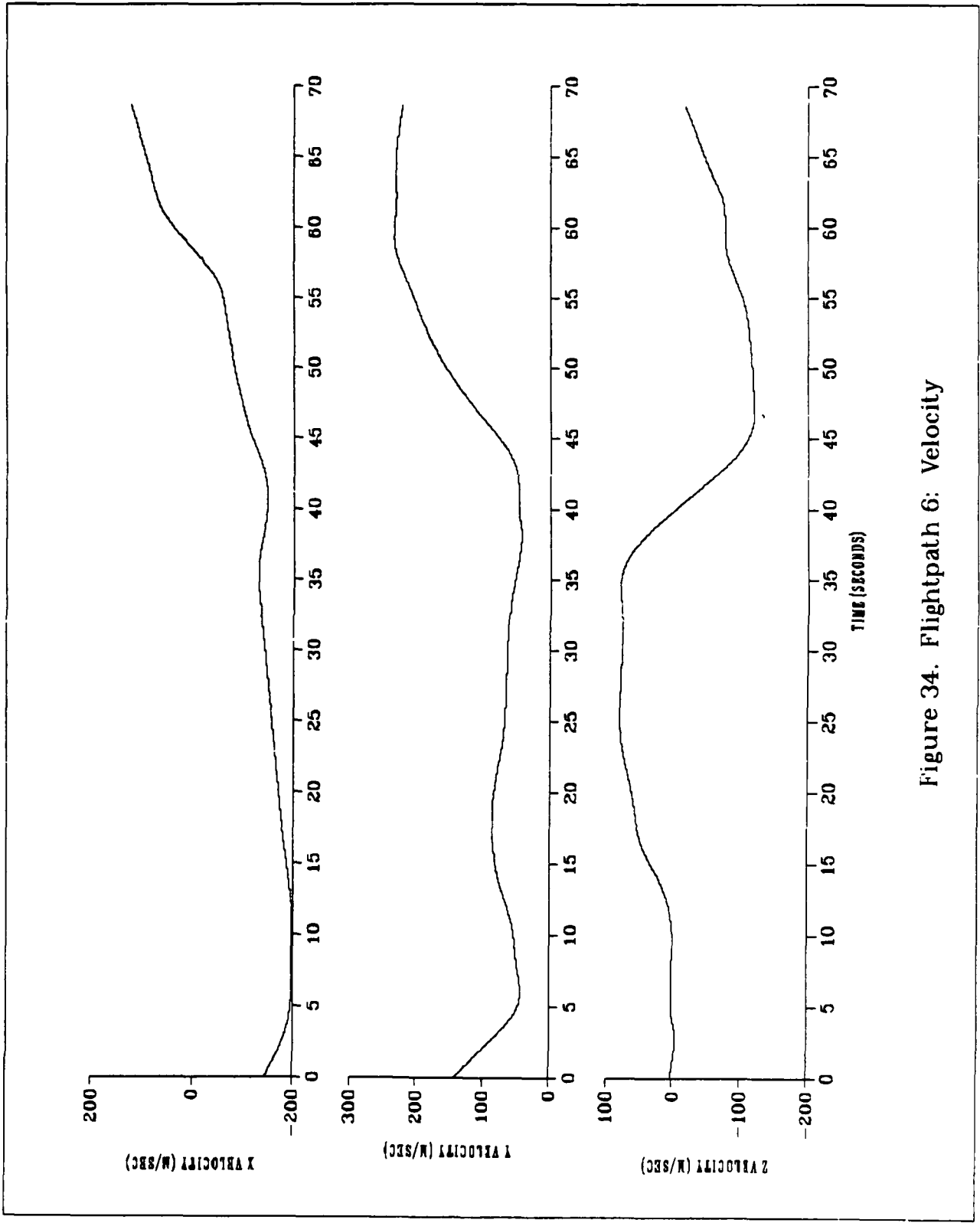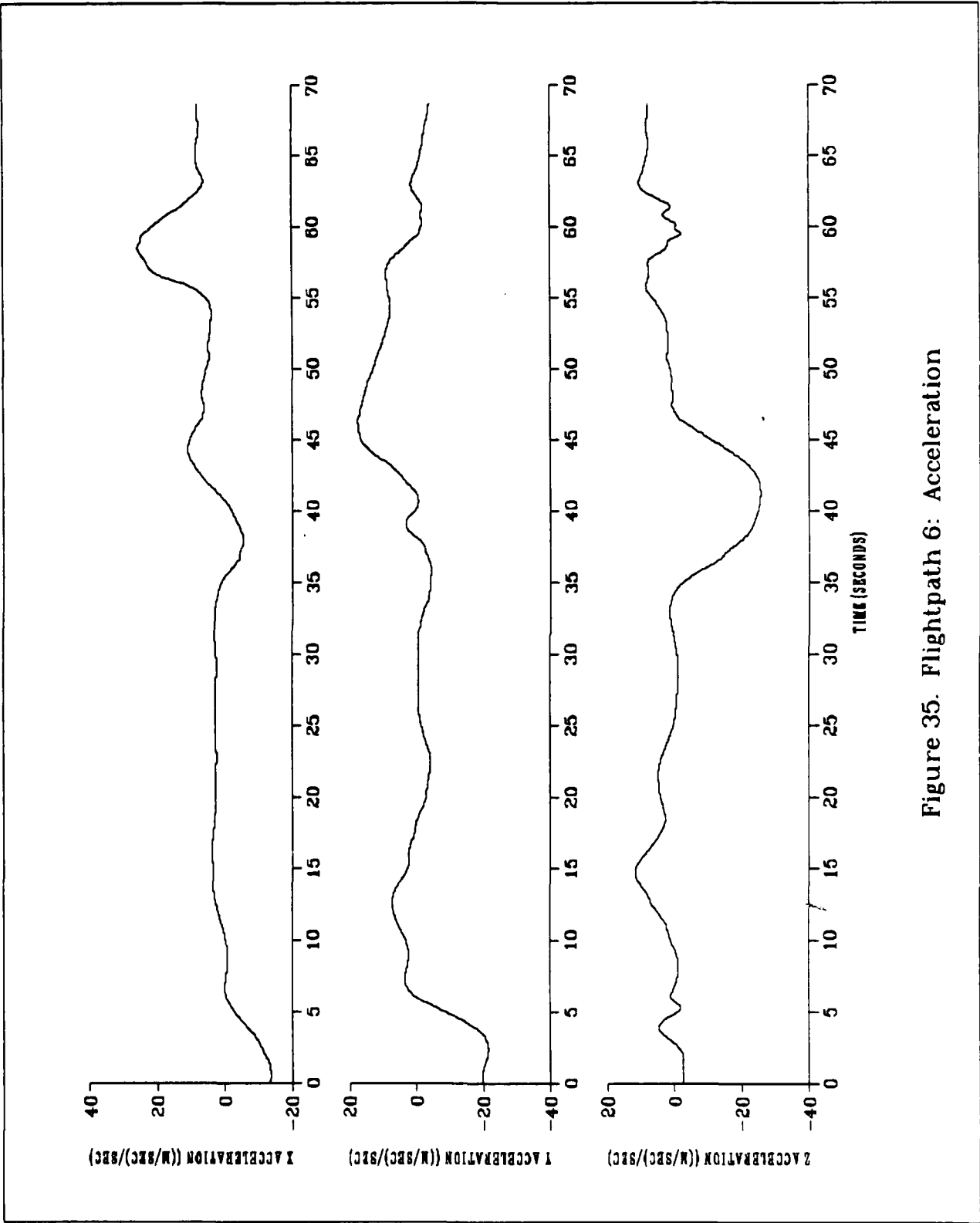Figure 10. Flightpath 2: Velocity

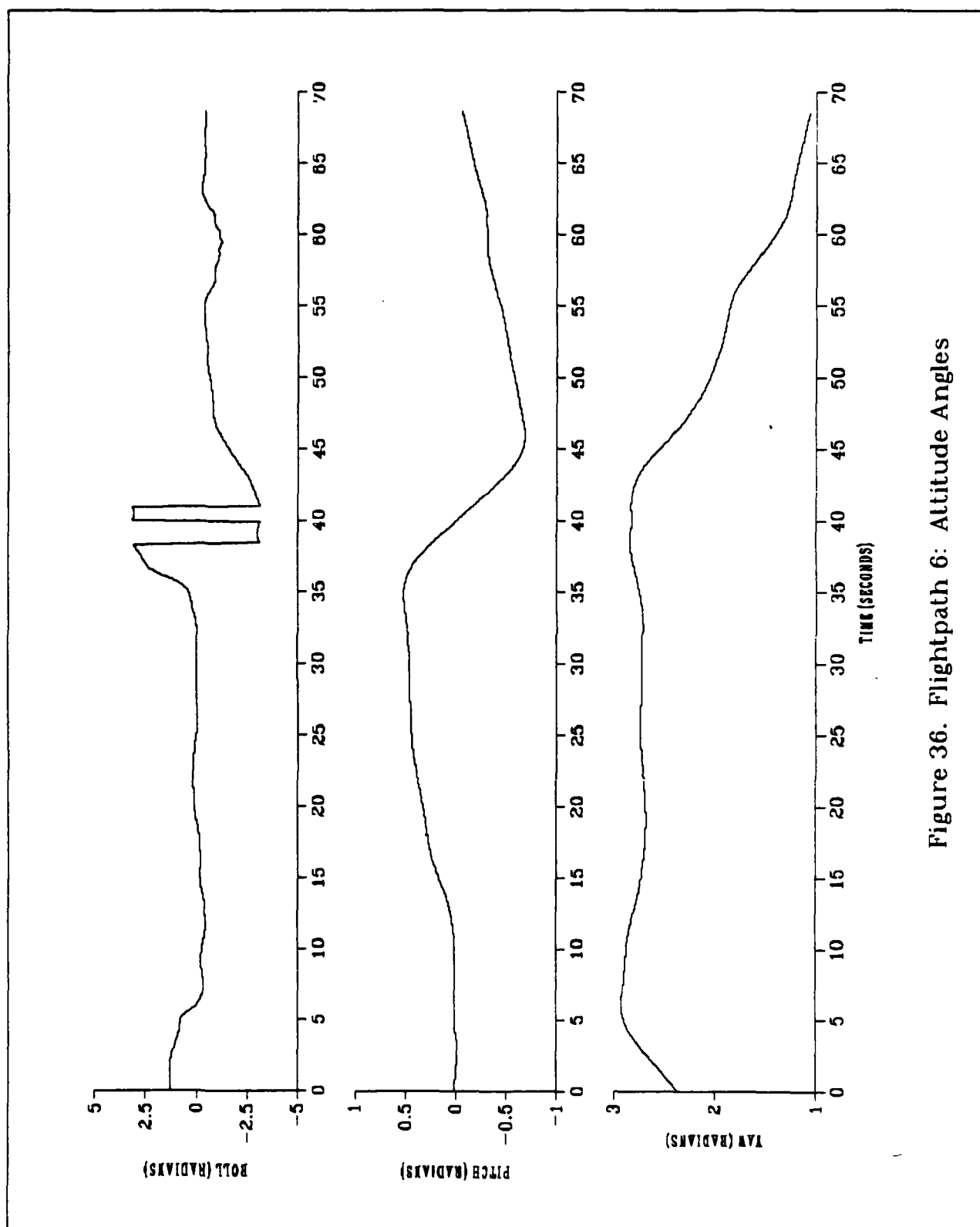Figure 11. Flightpath 2: Acceleration

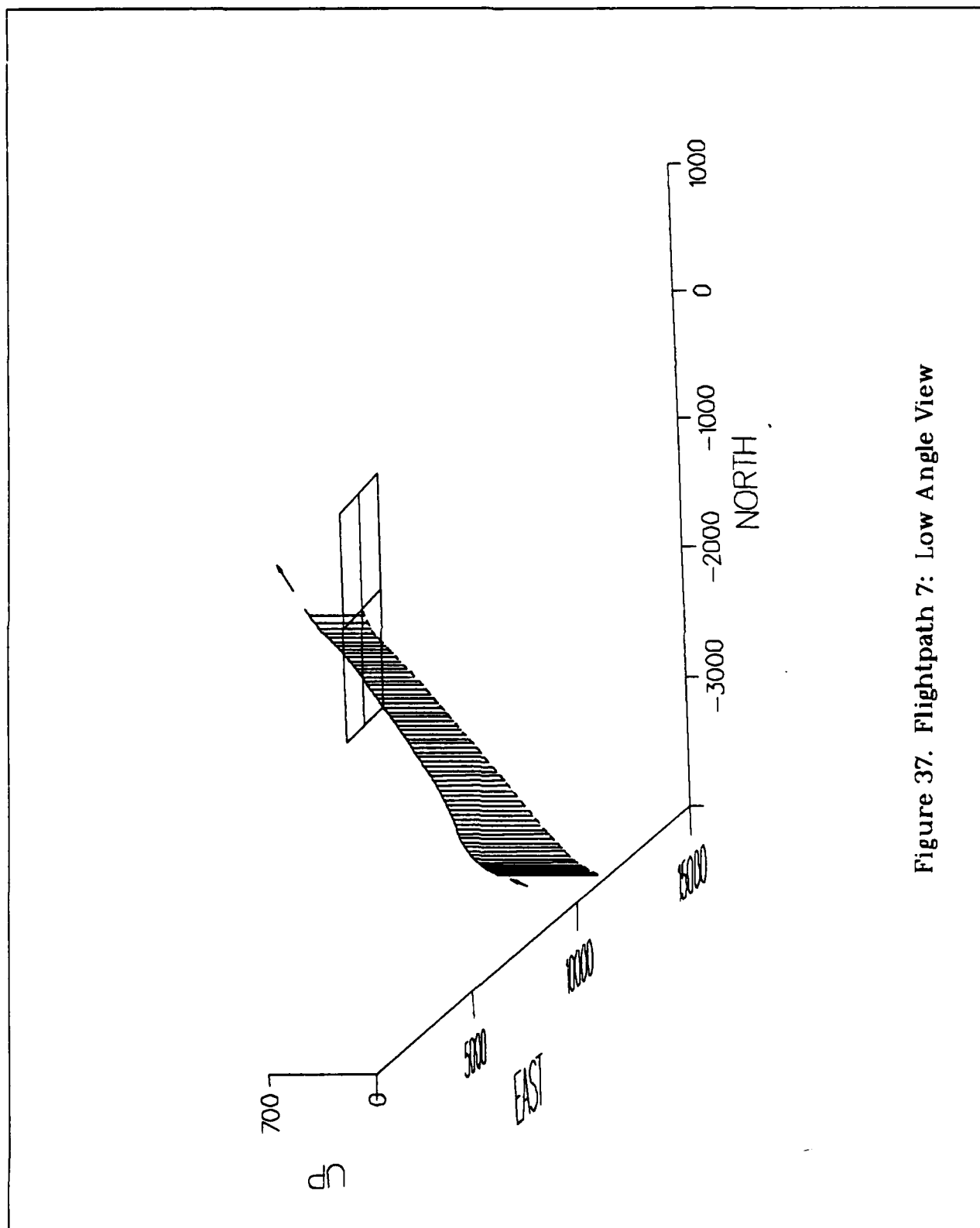Figure 12. Flightpath 2: Attitude Angles

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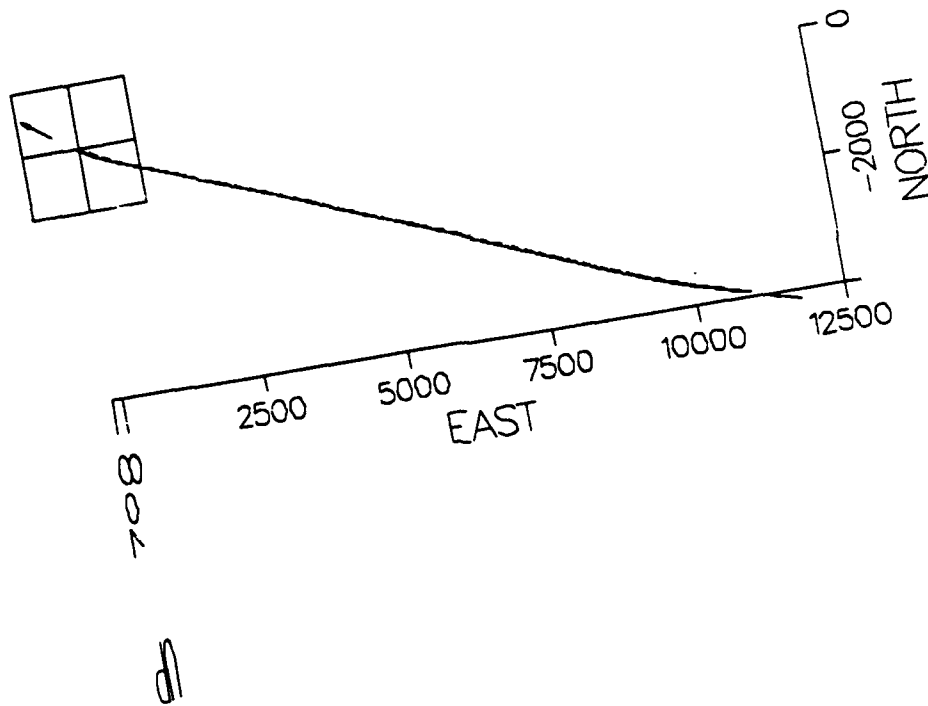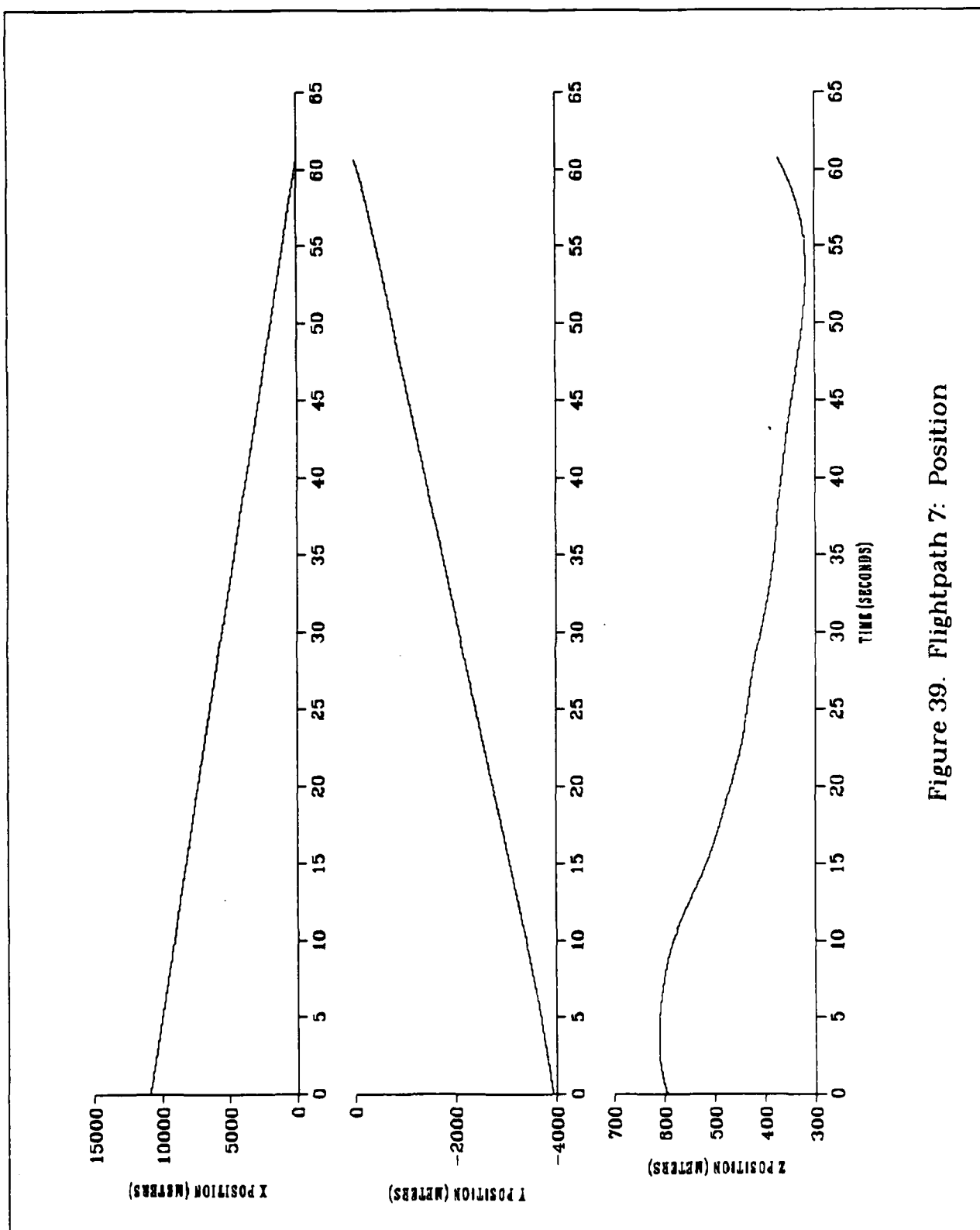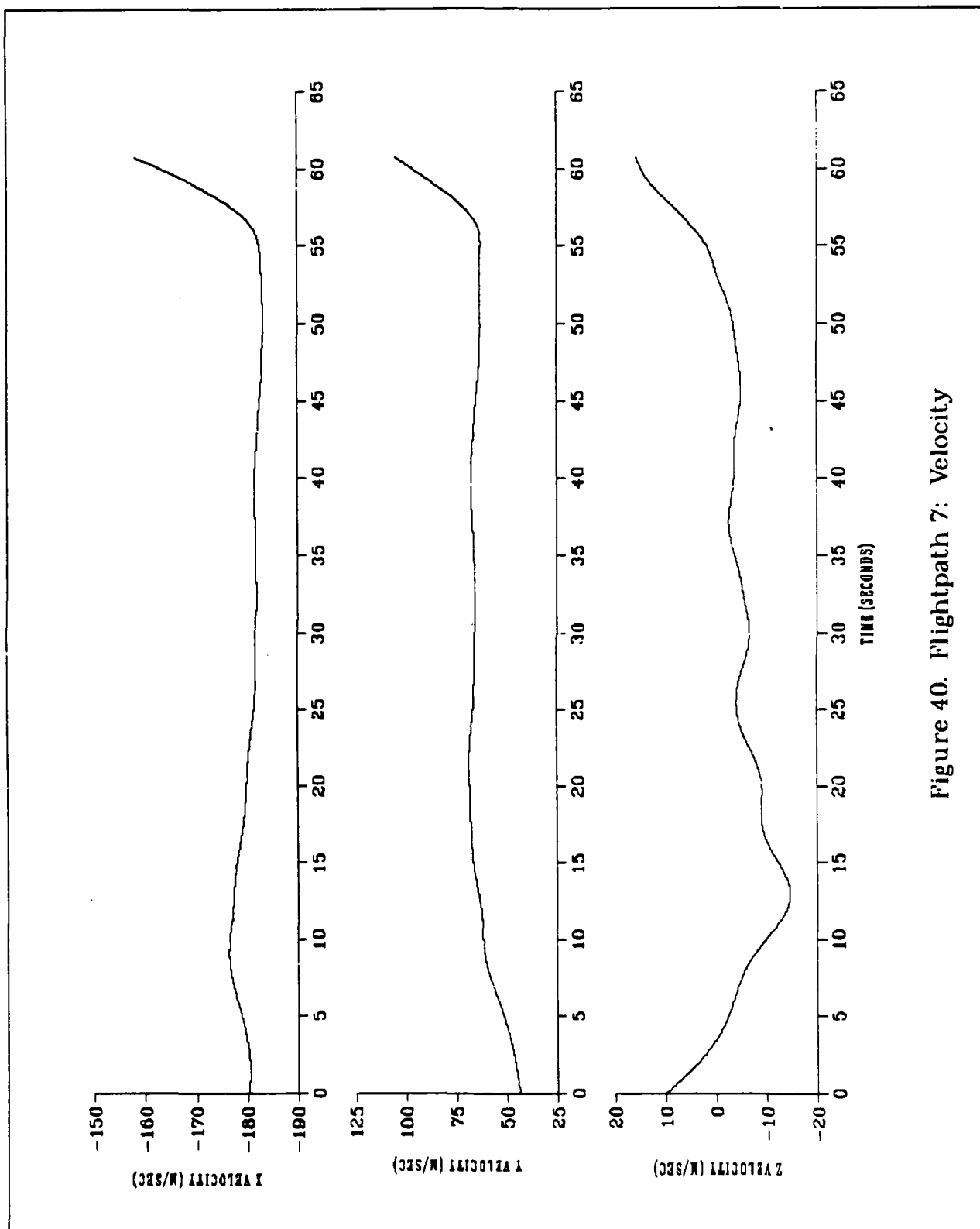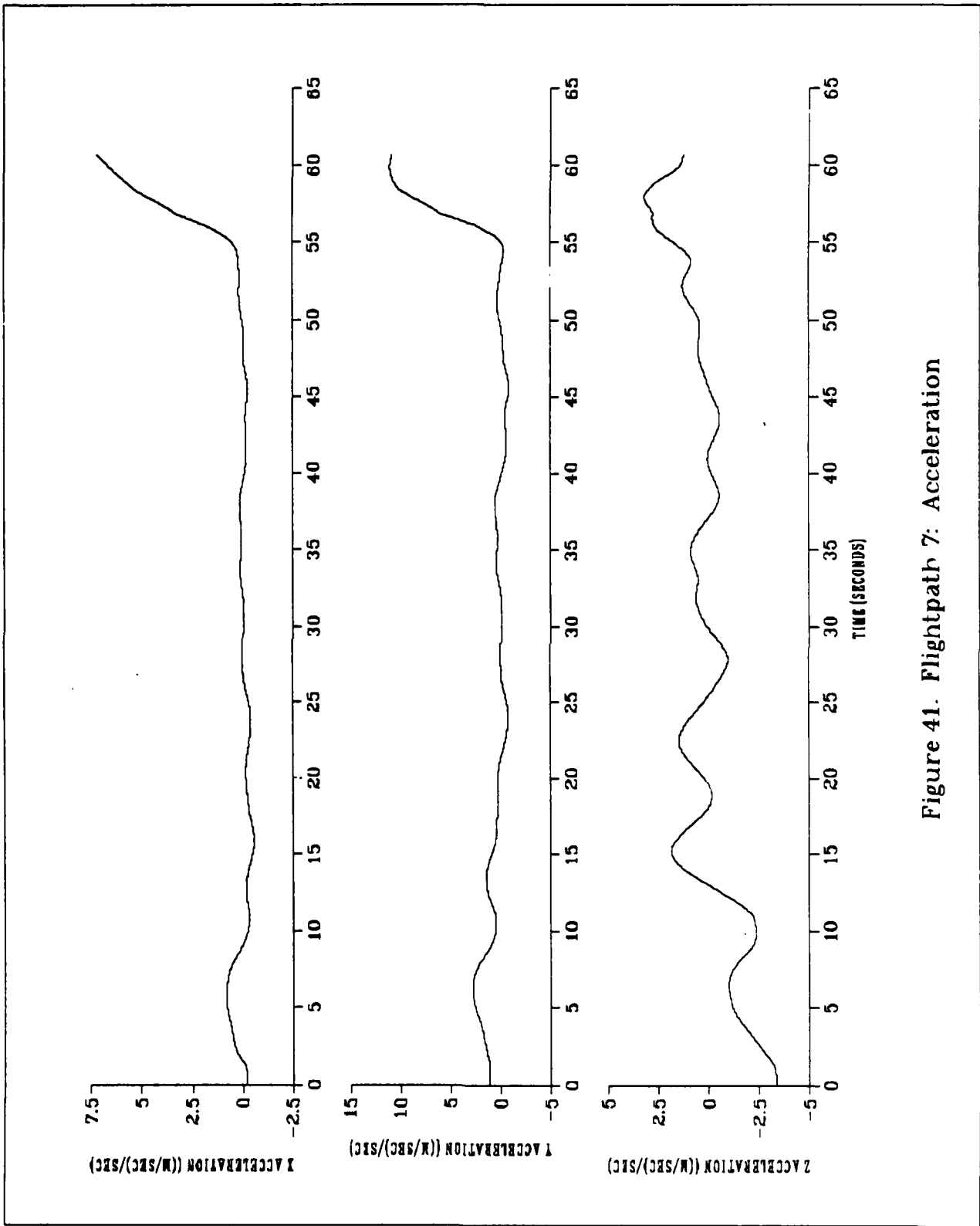
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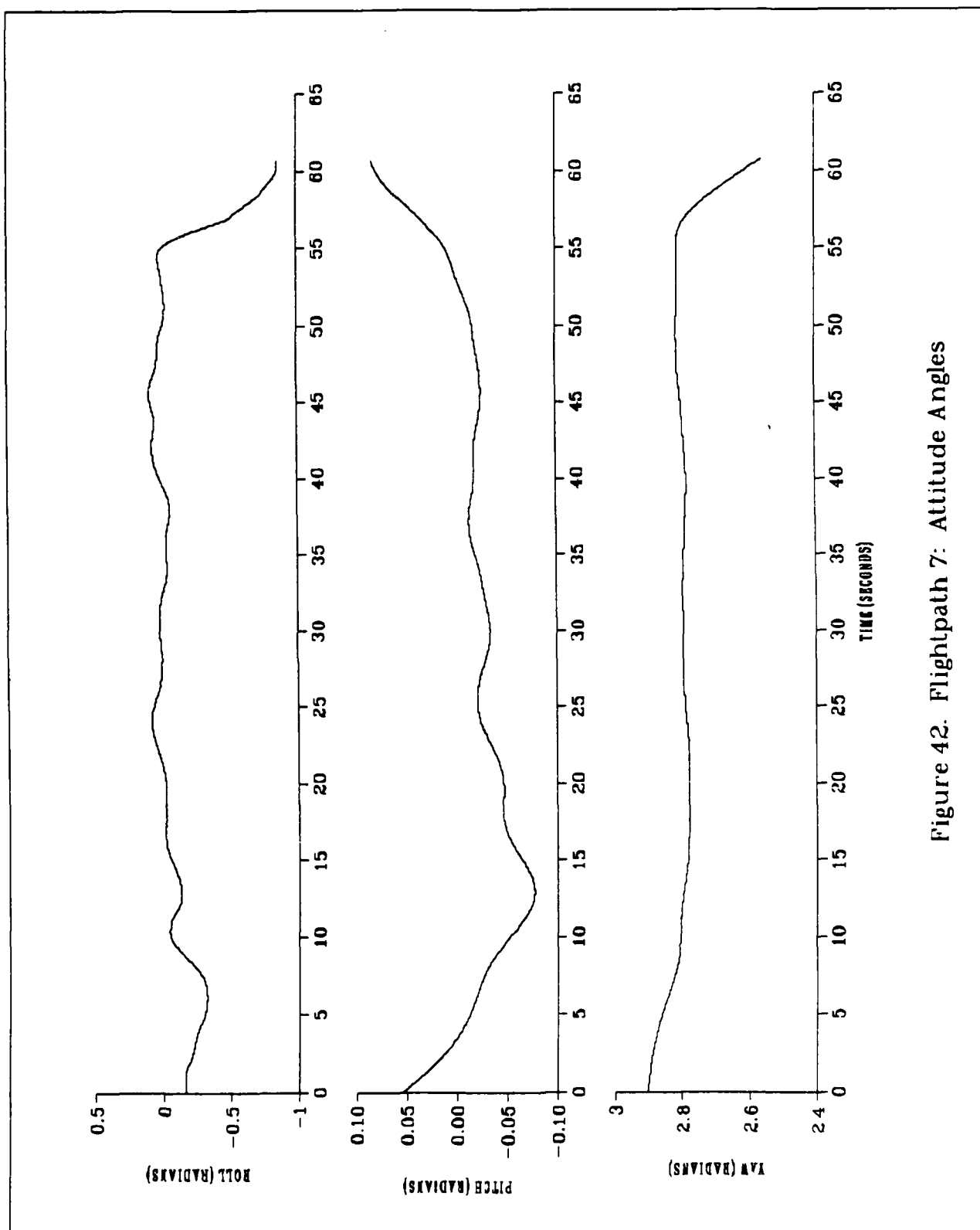
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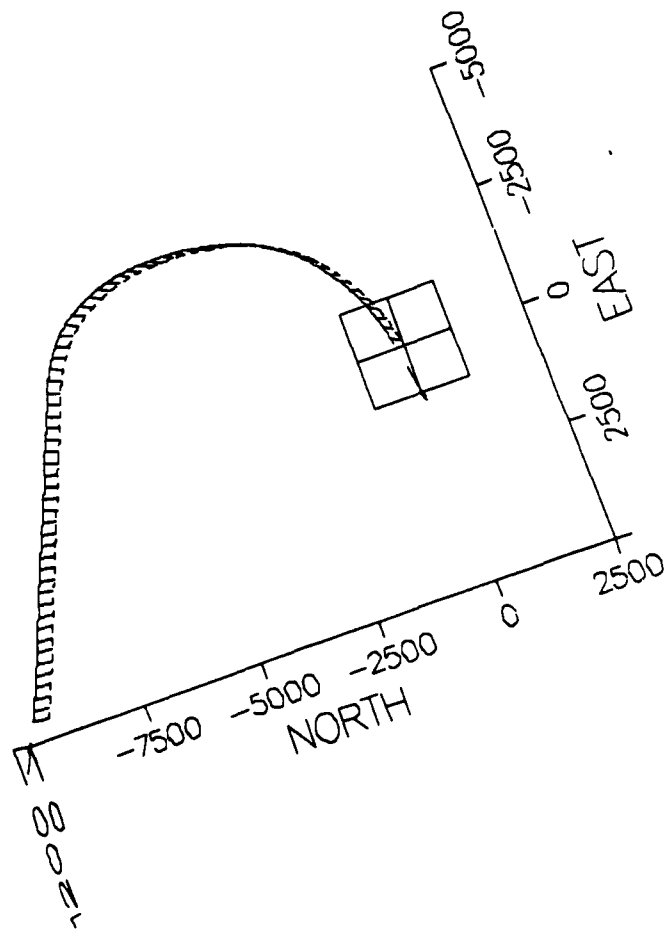
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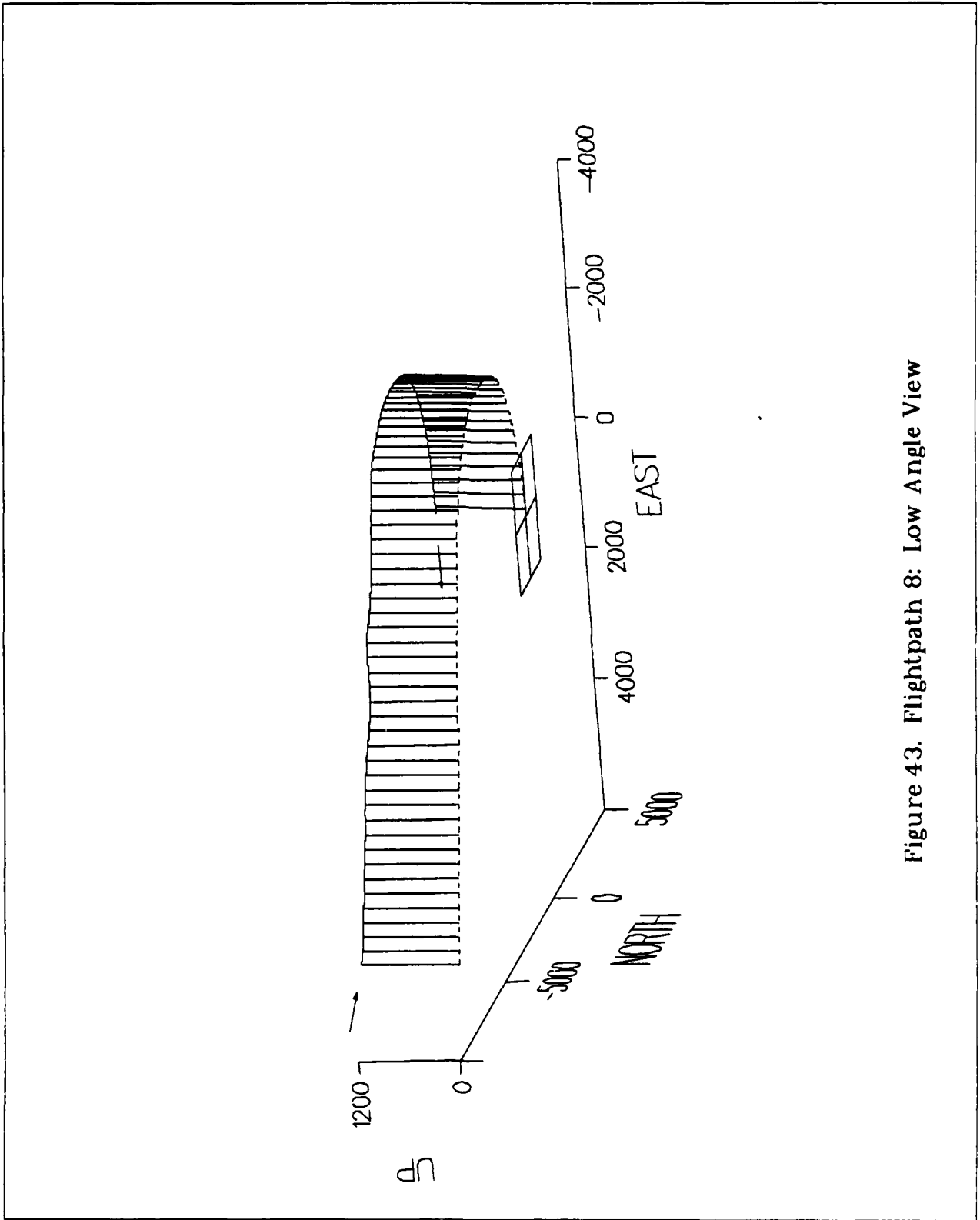
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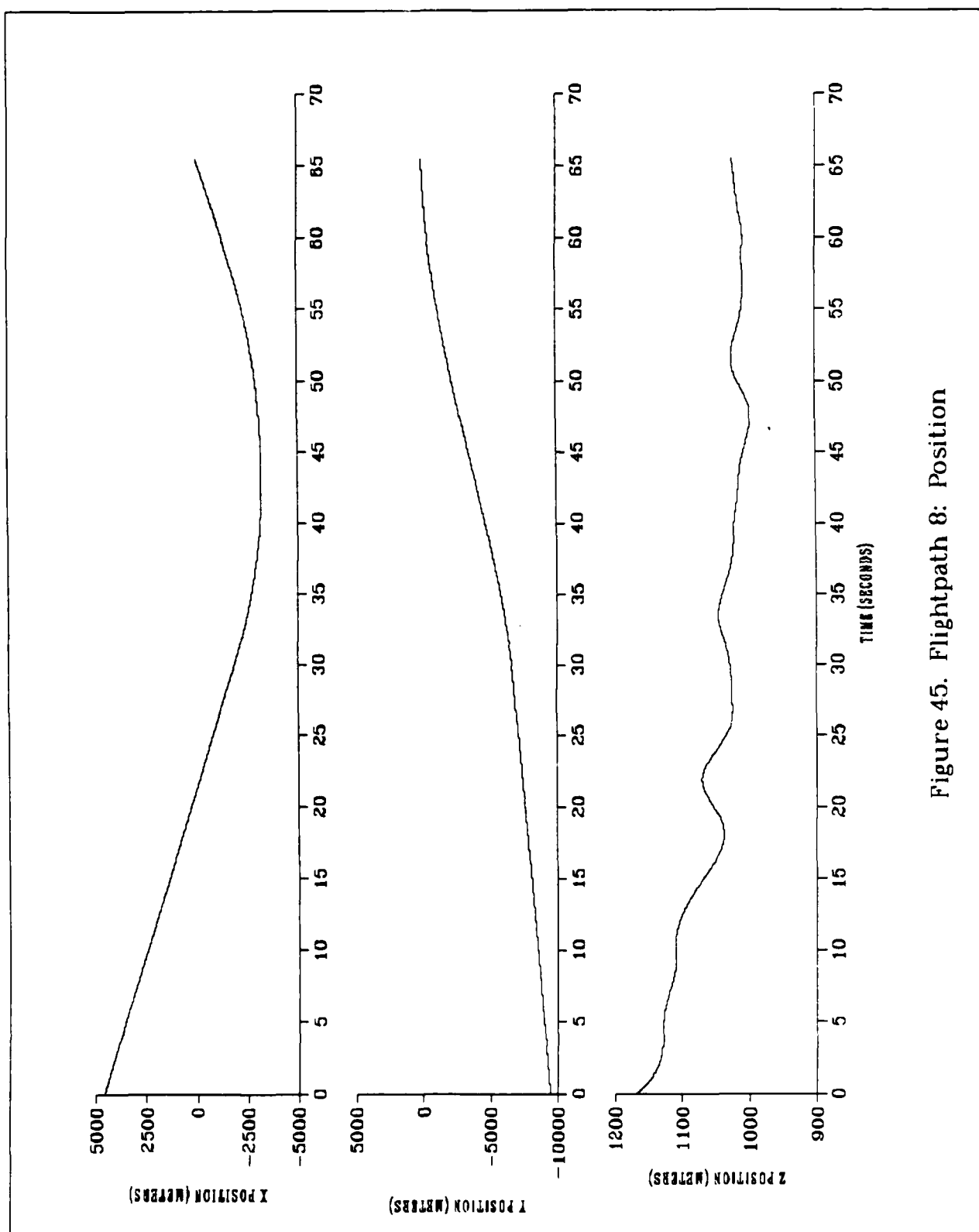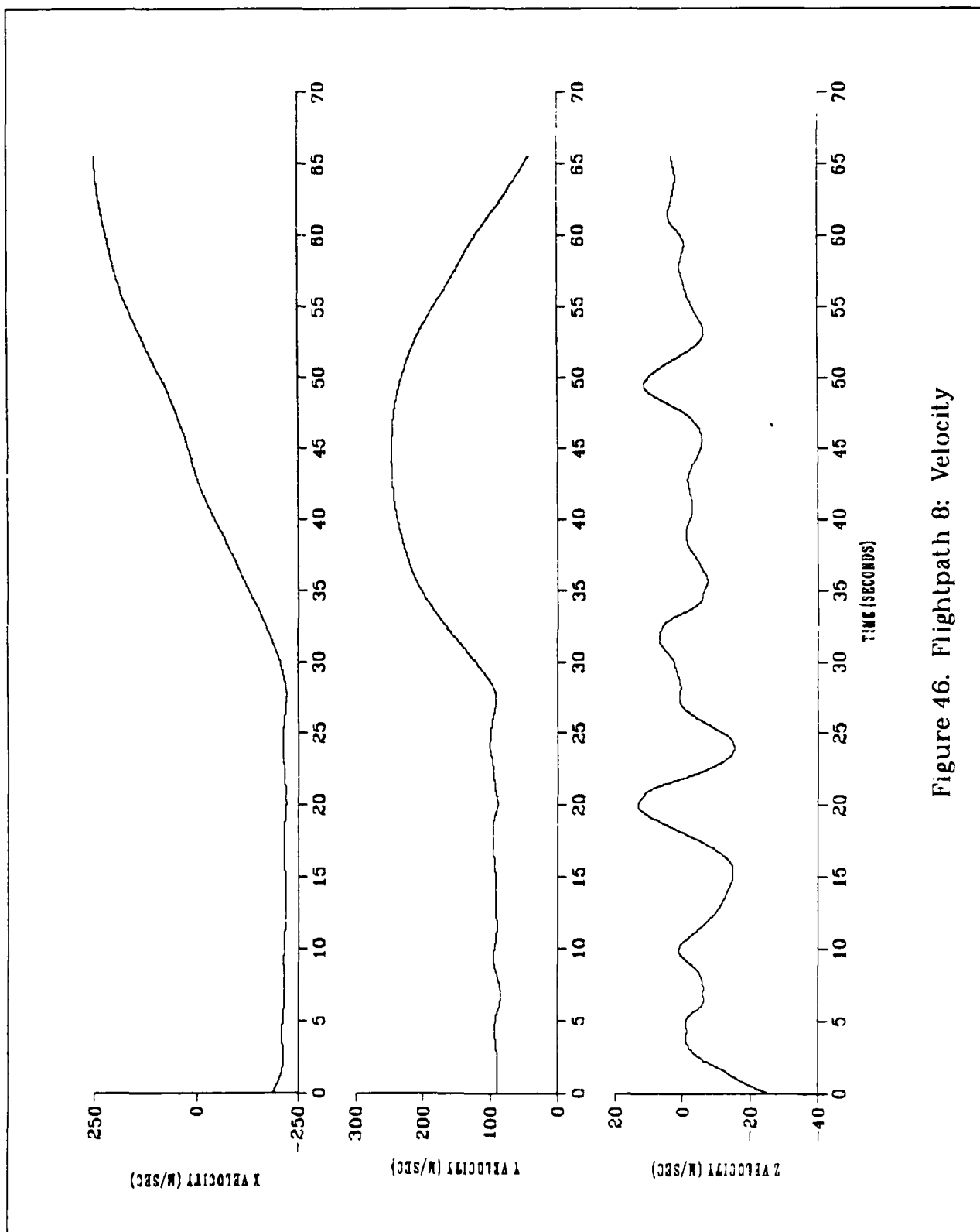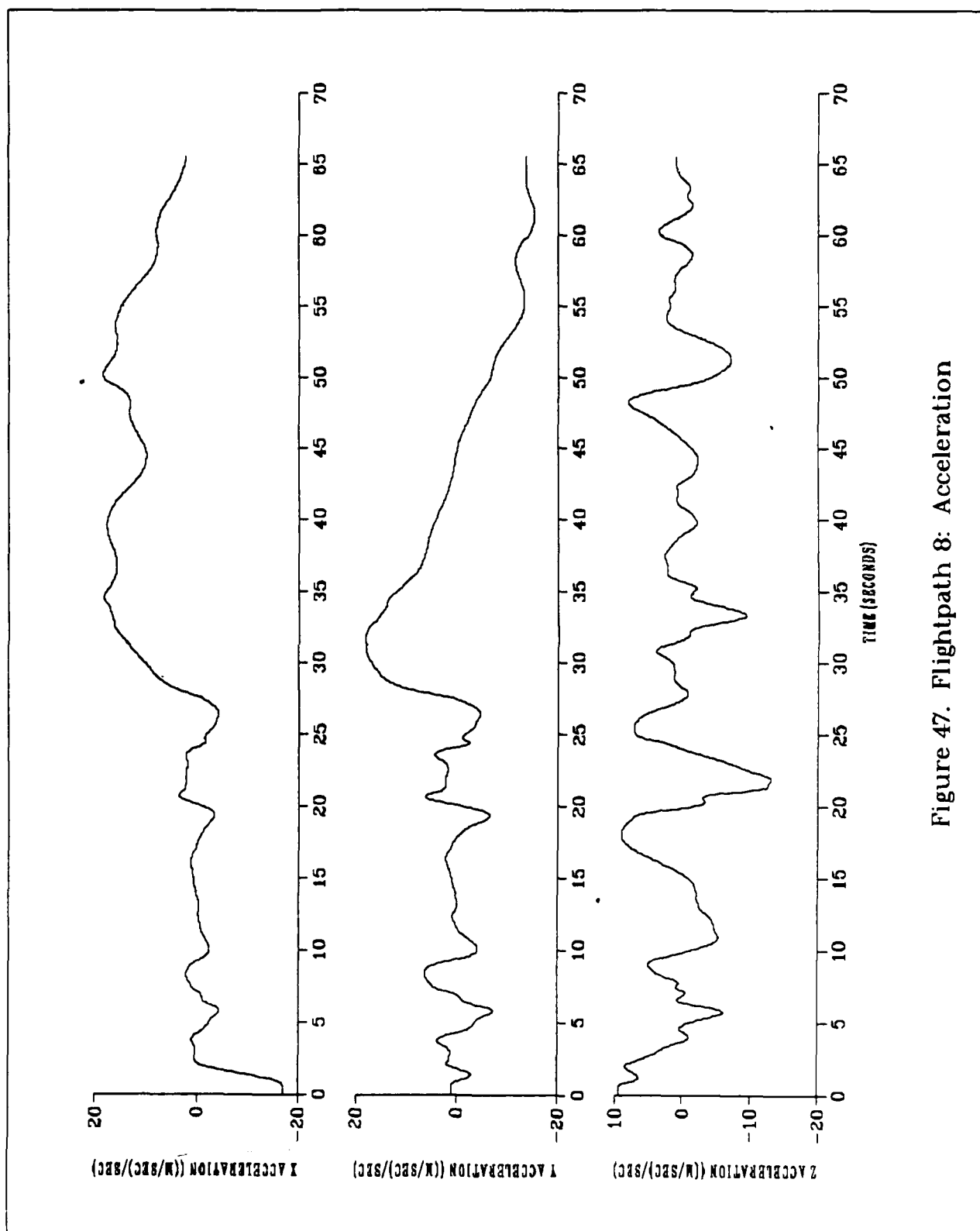
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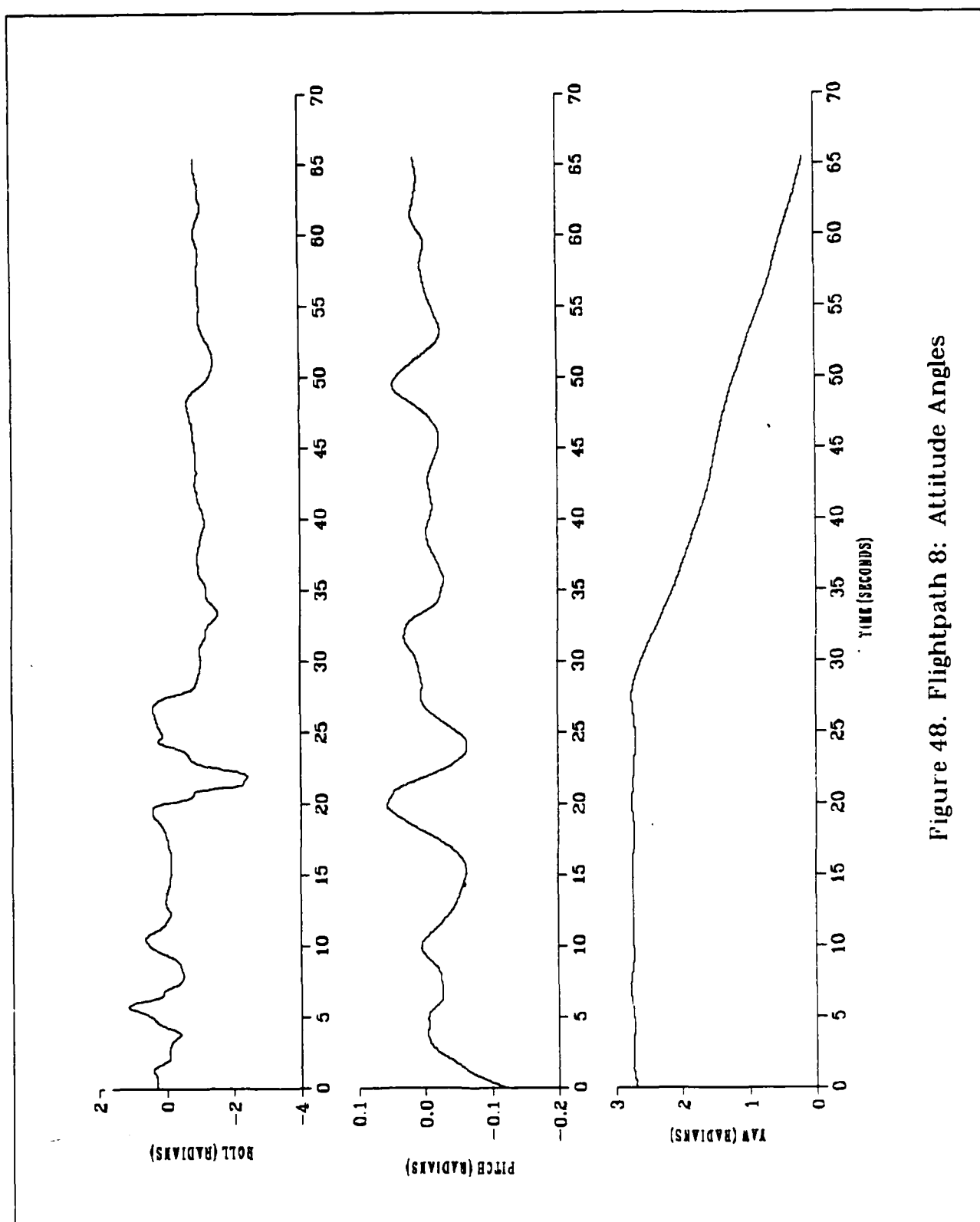
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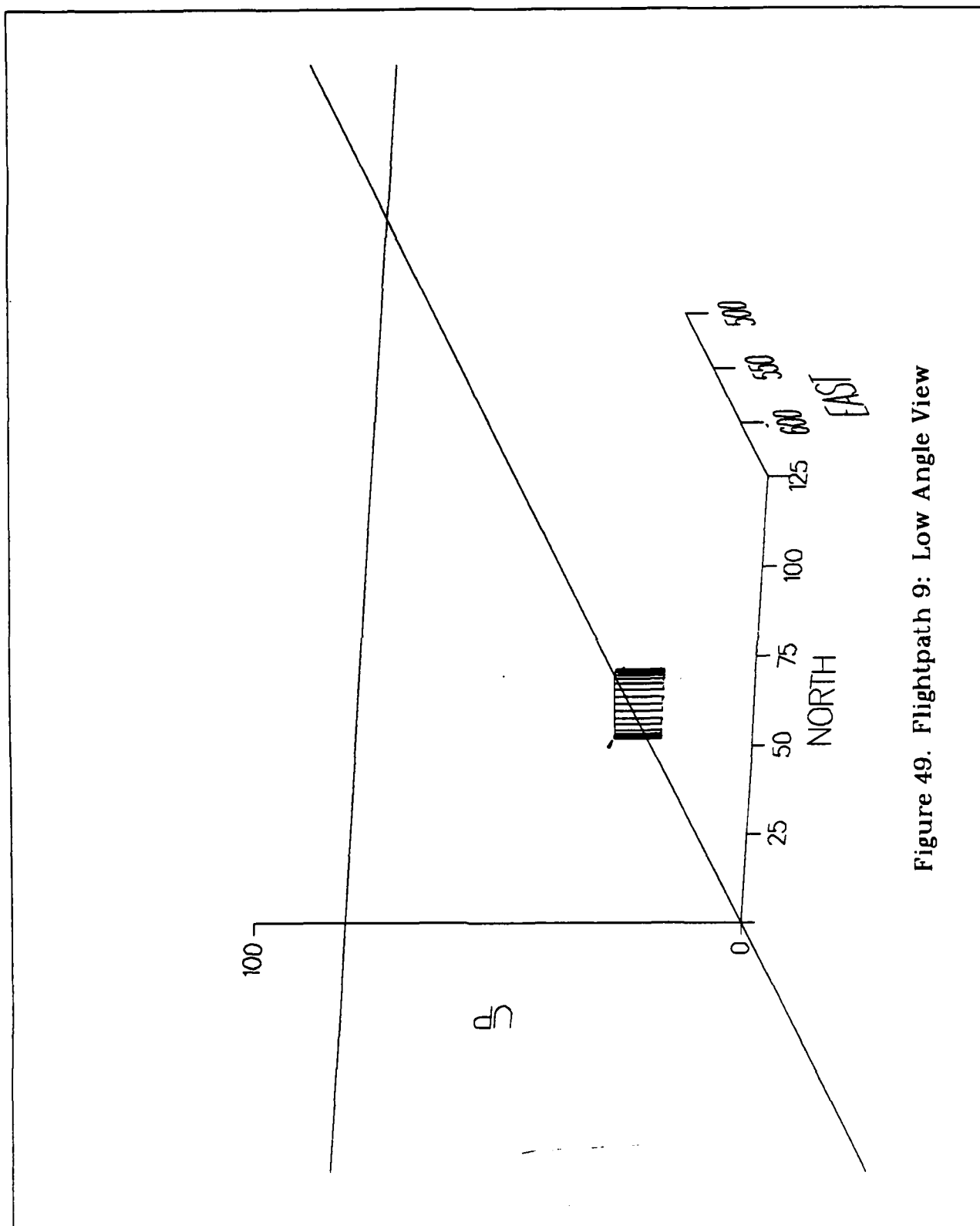
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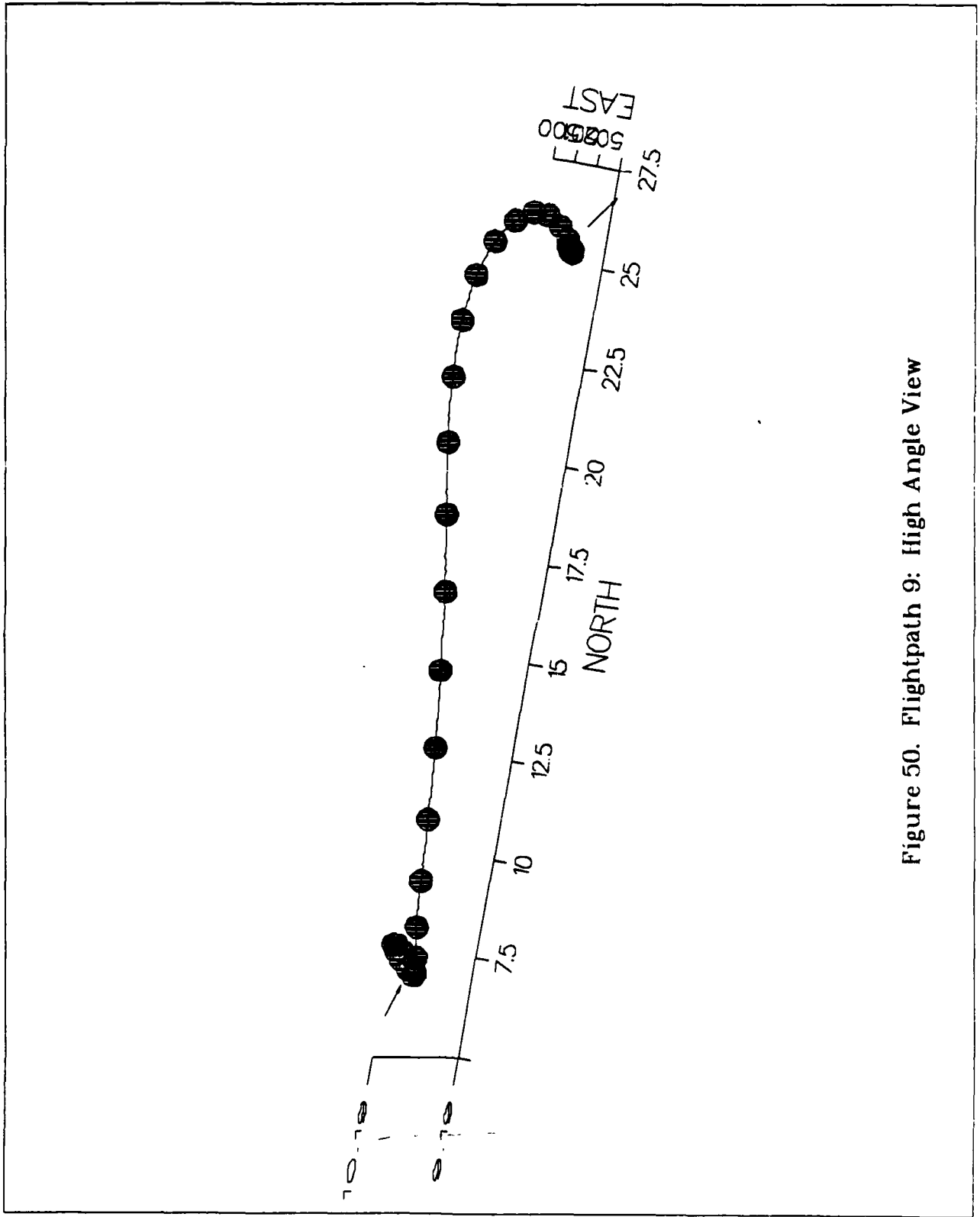Figure 49. Flightpath 9: Low Angle View
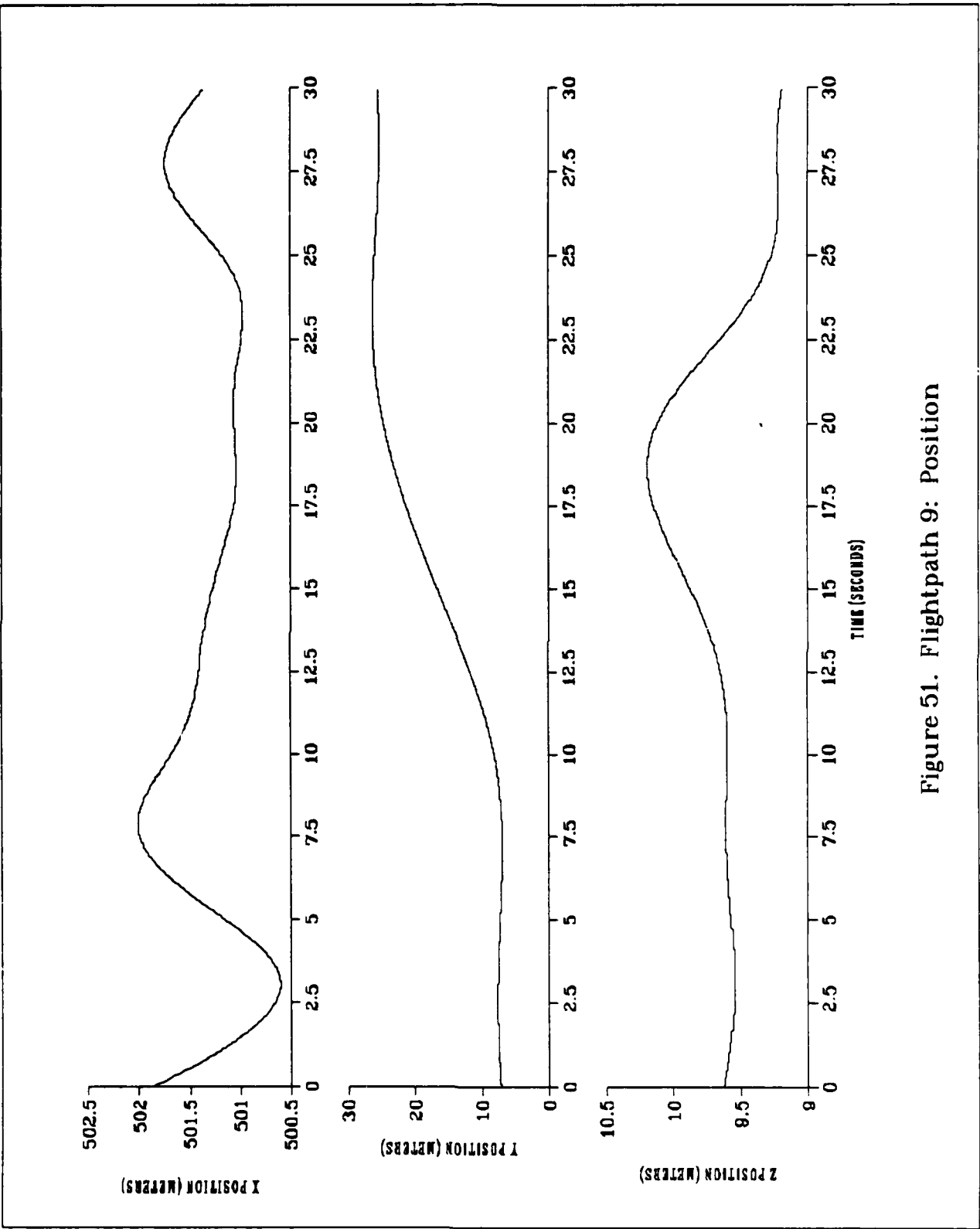
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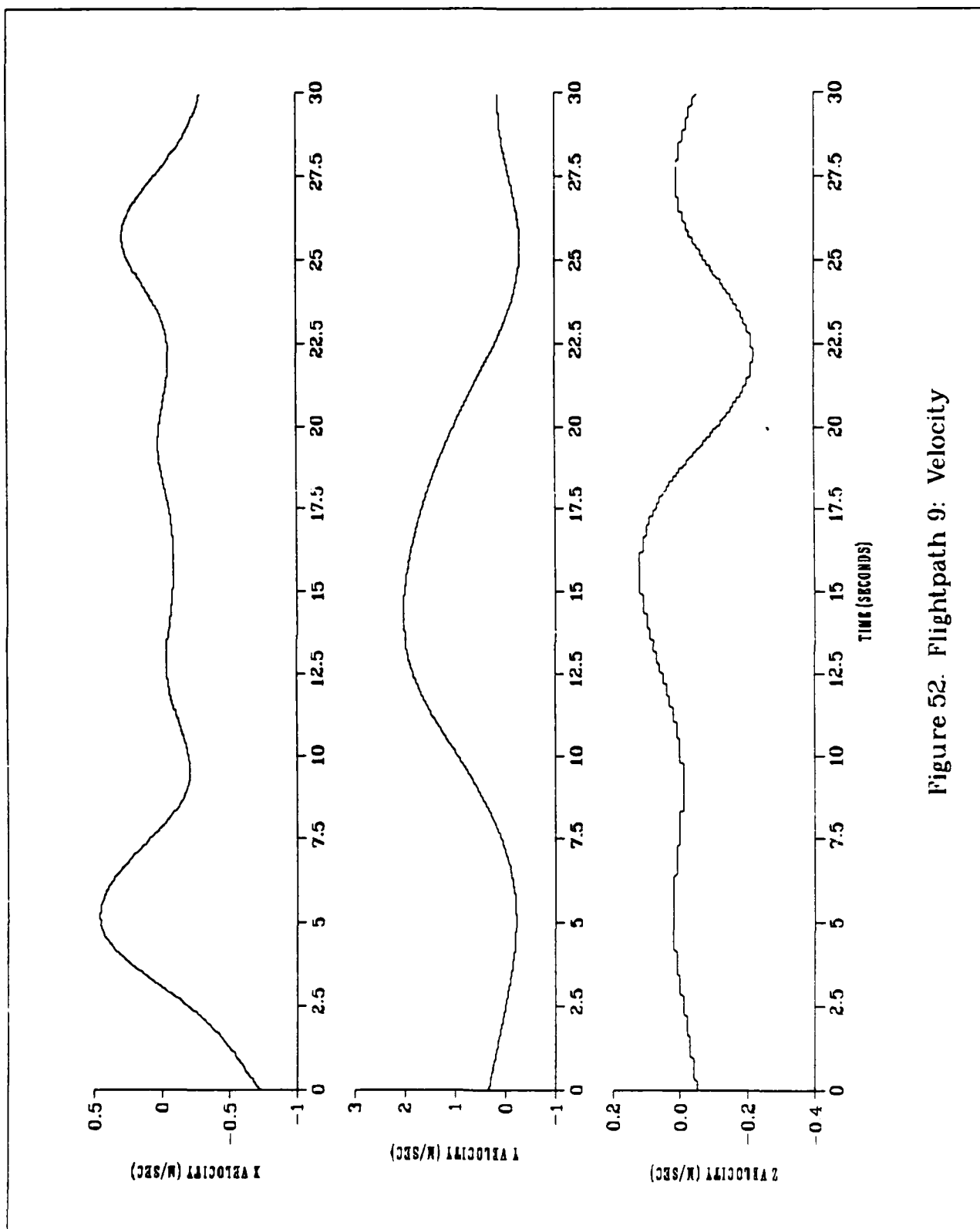
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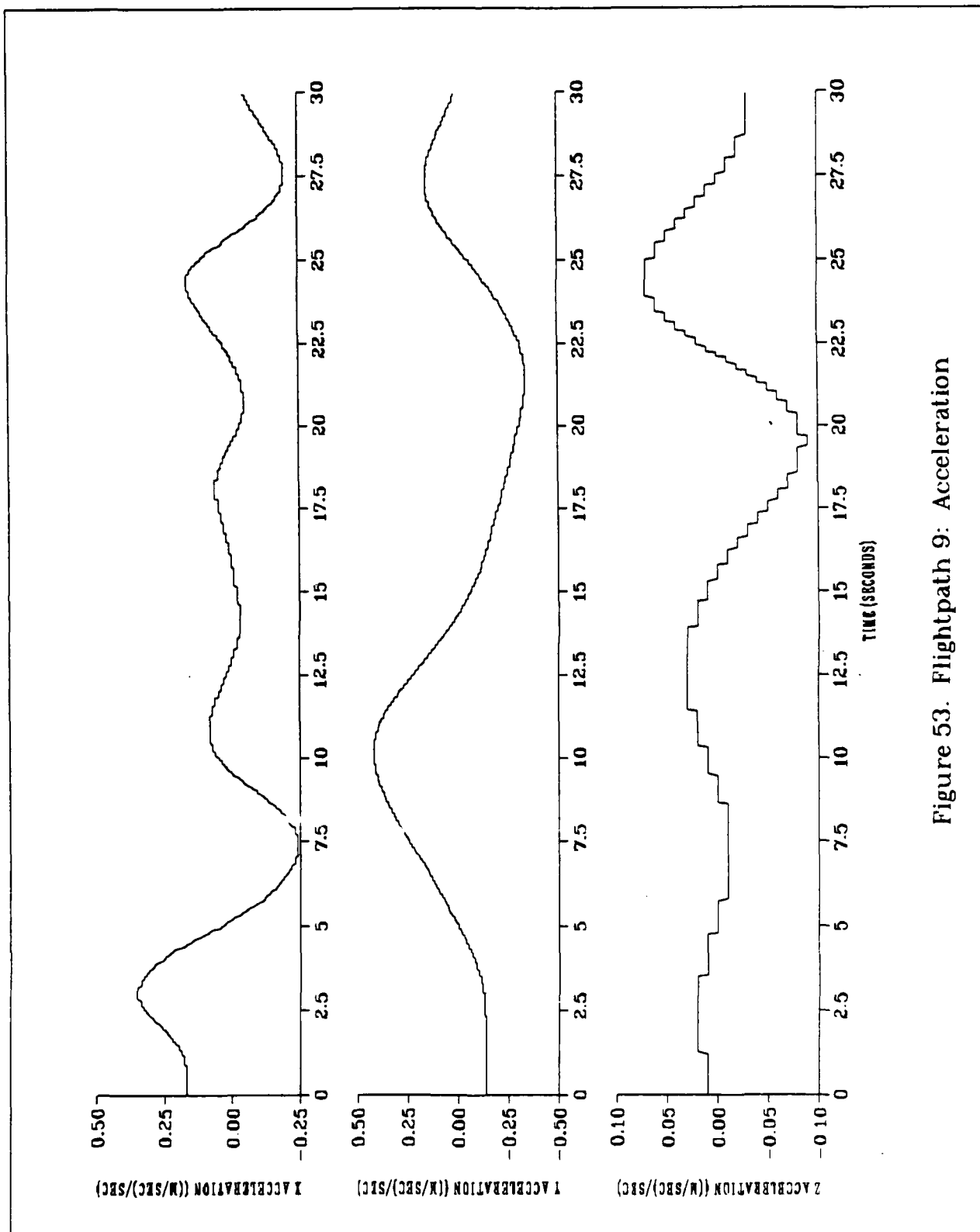
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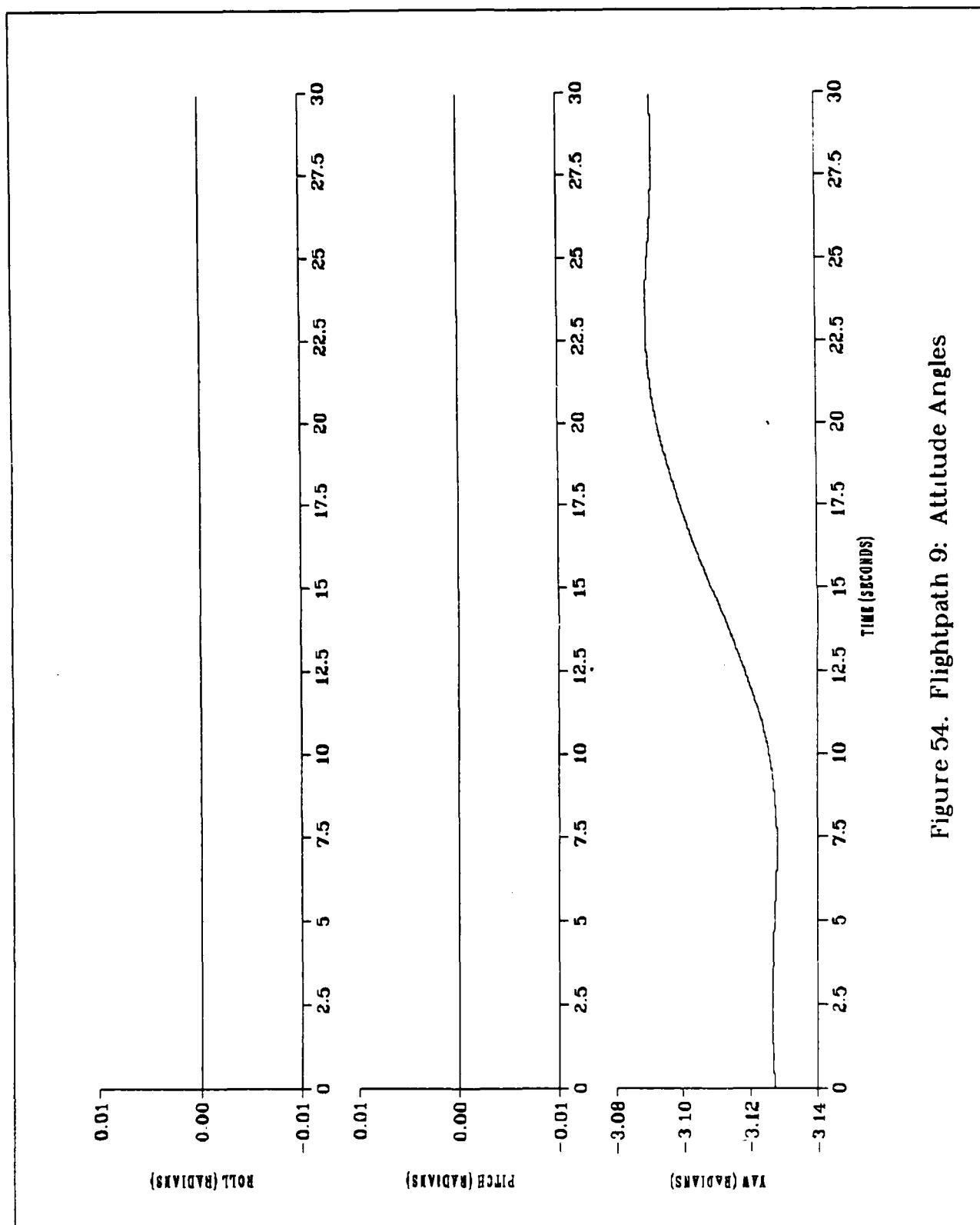Figure 53. Flightpath 9: Acceleration
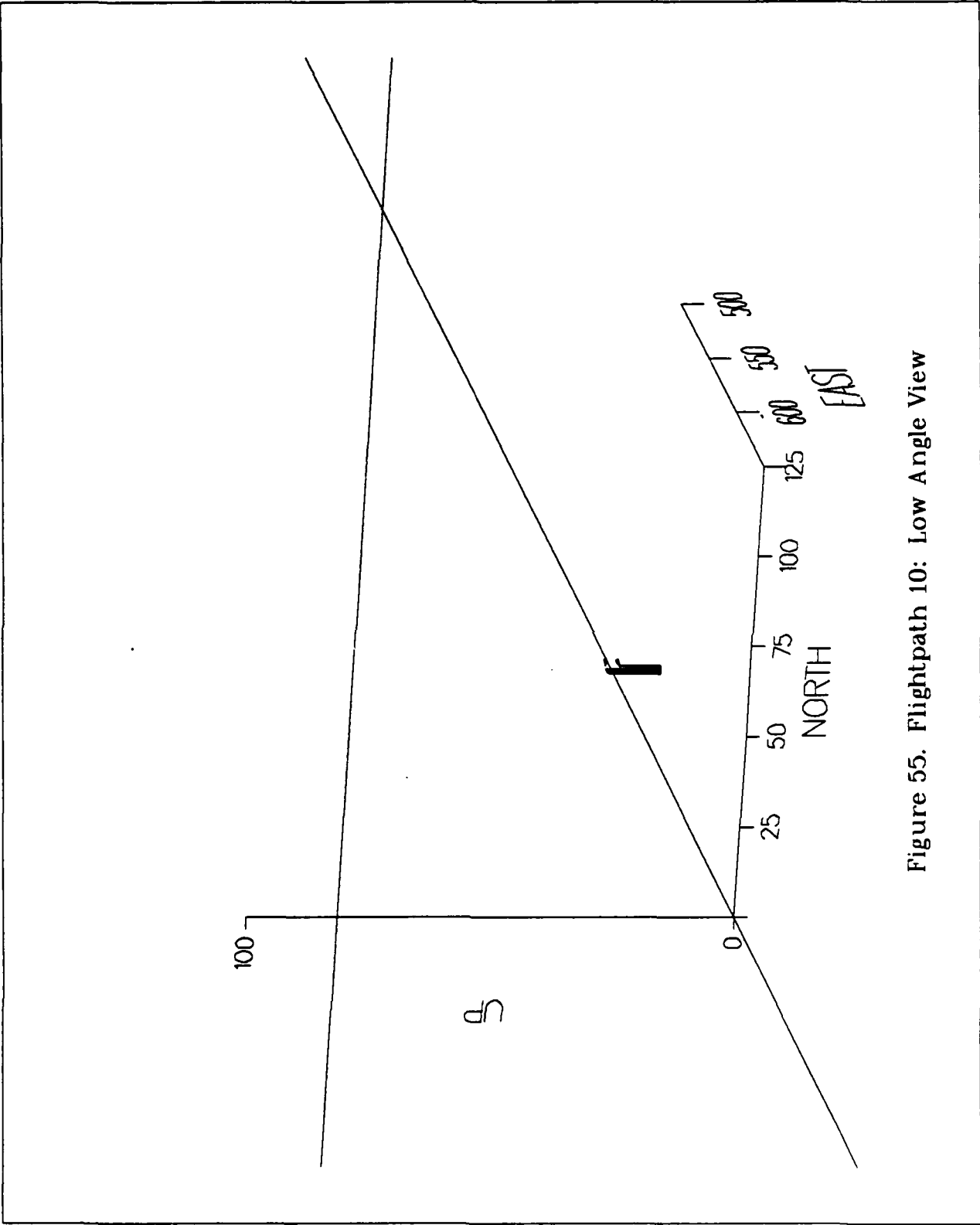
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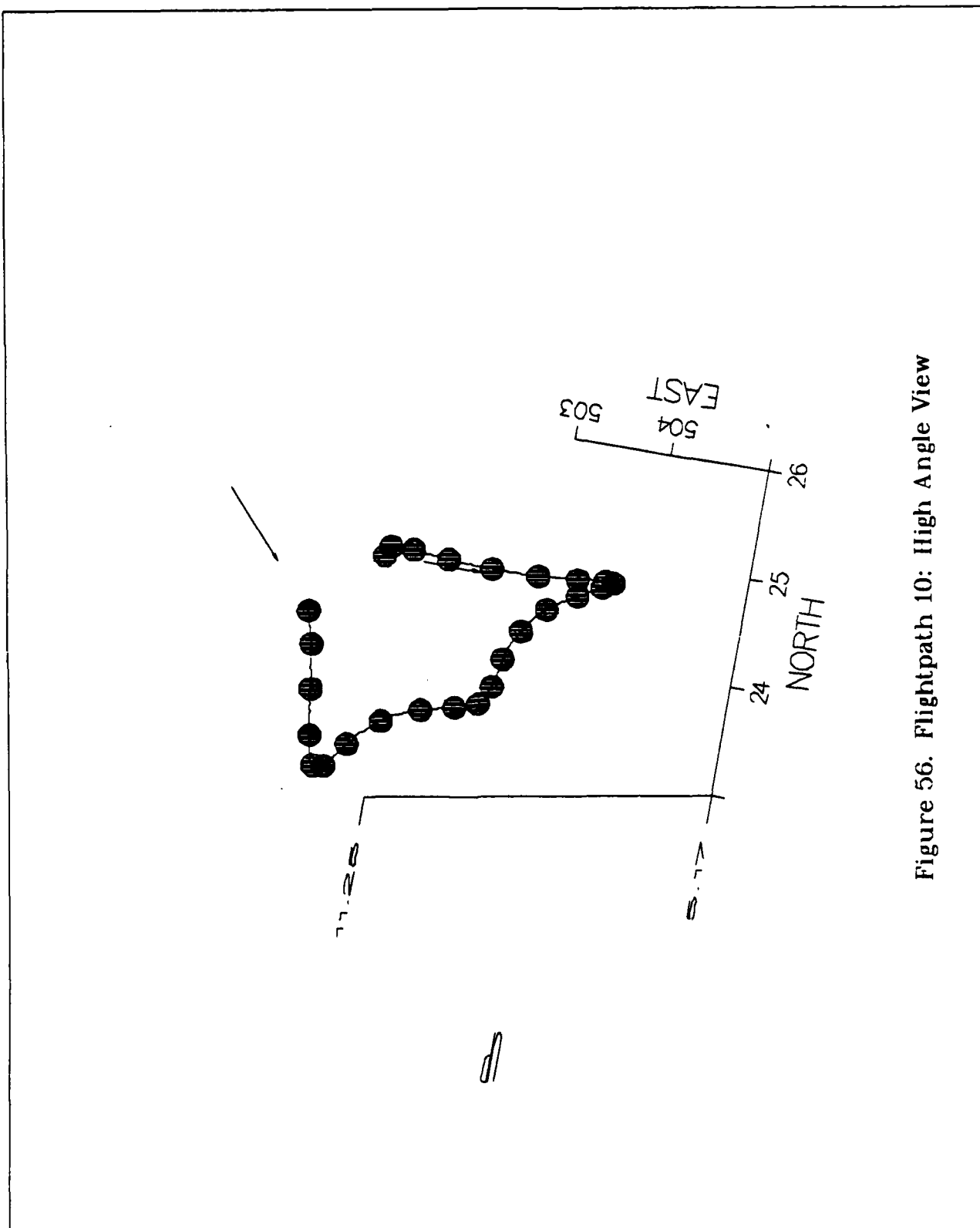
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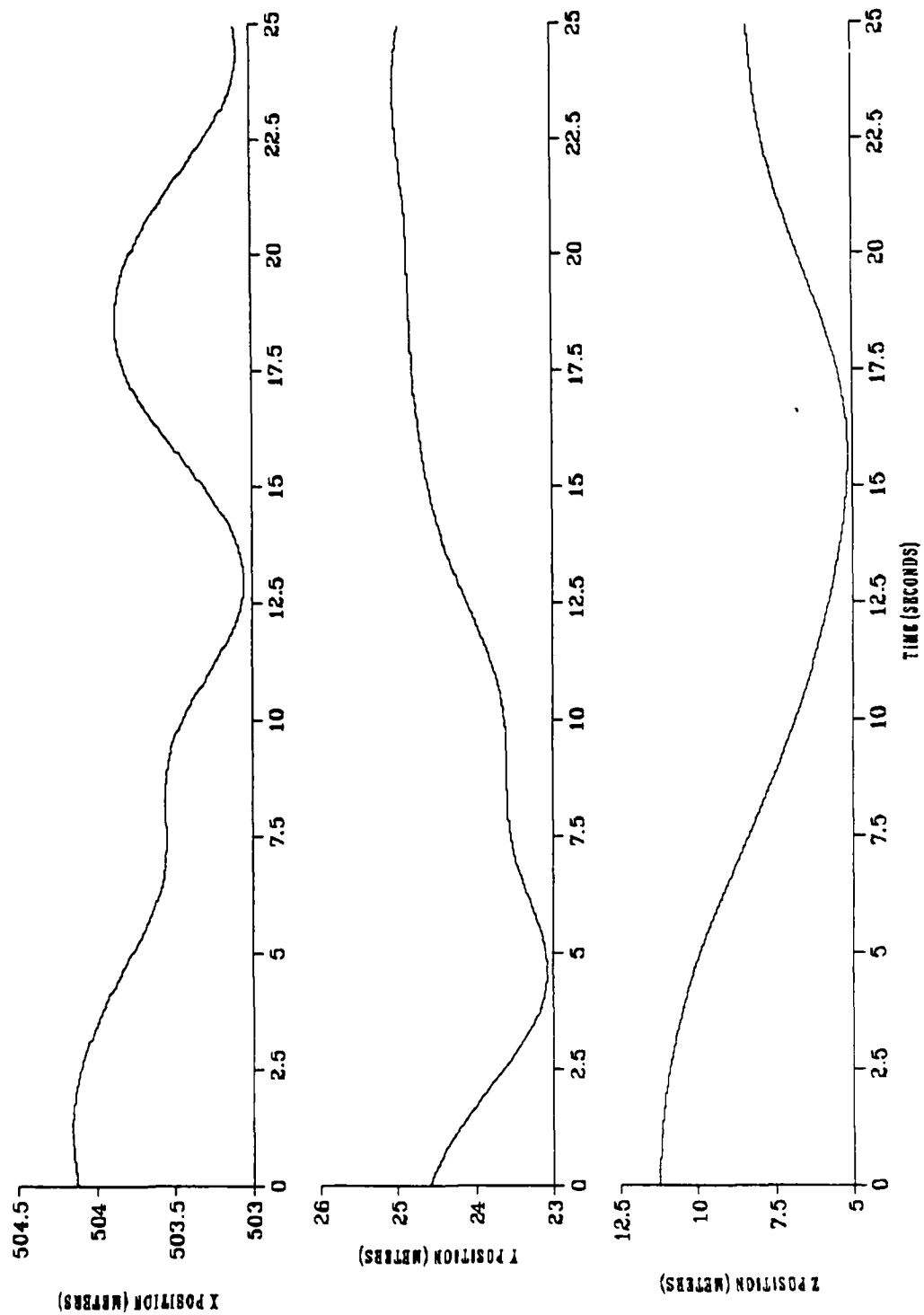65

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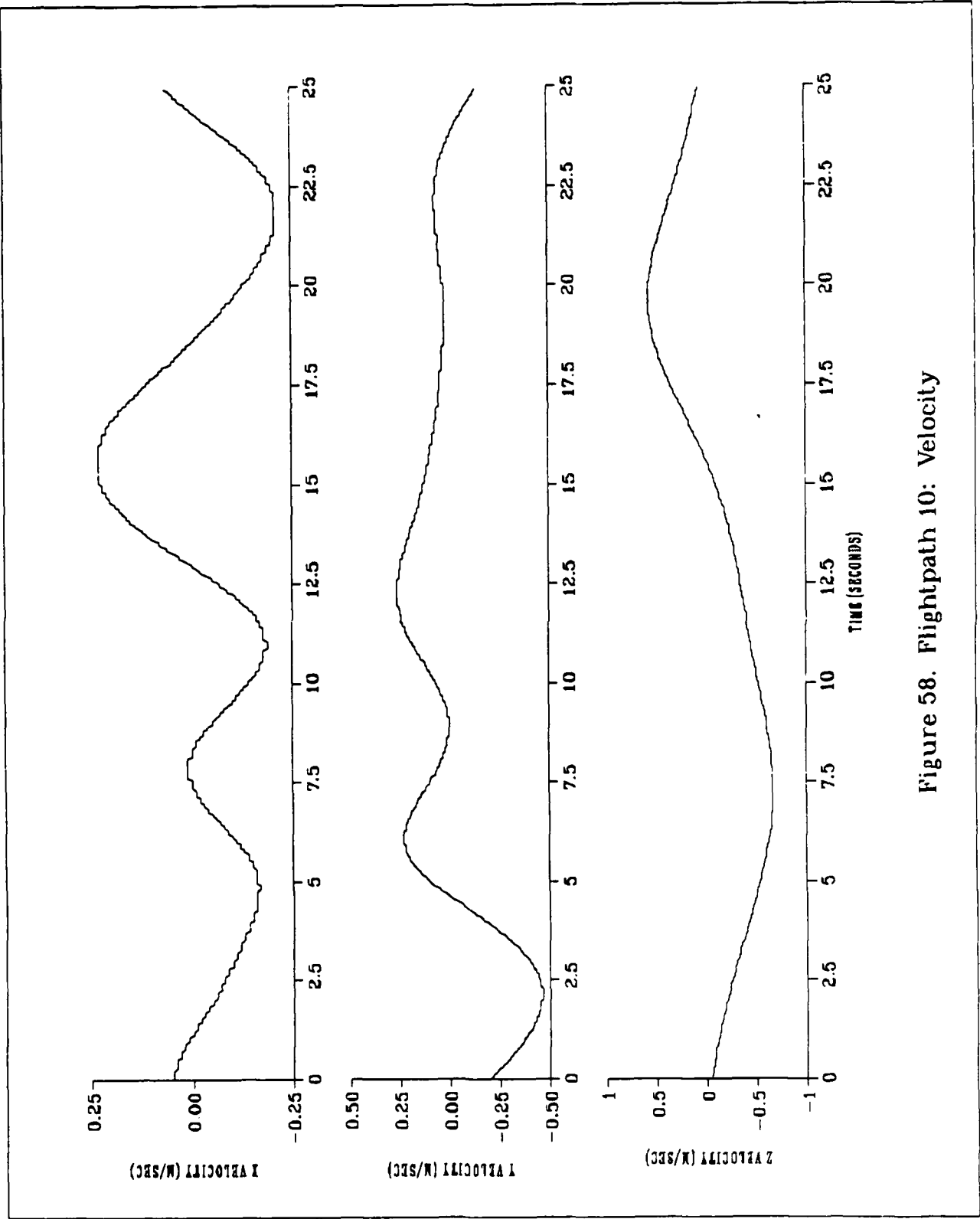
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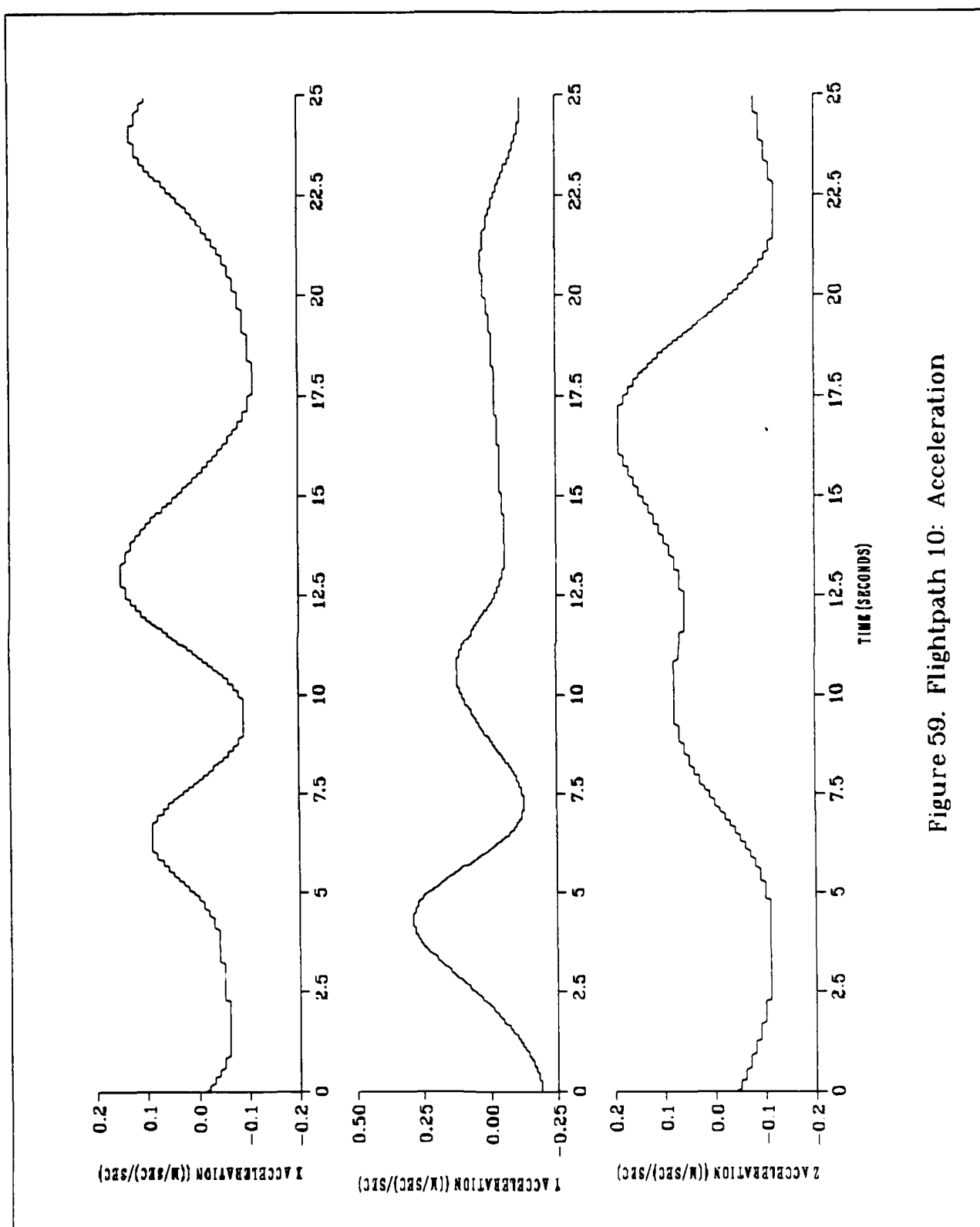73

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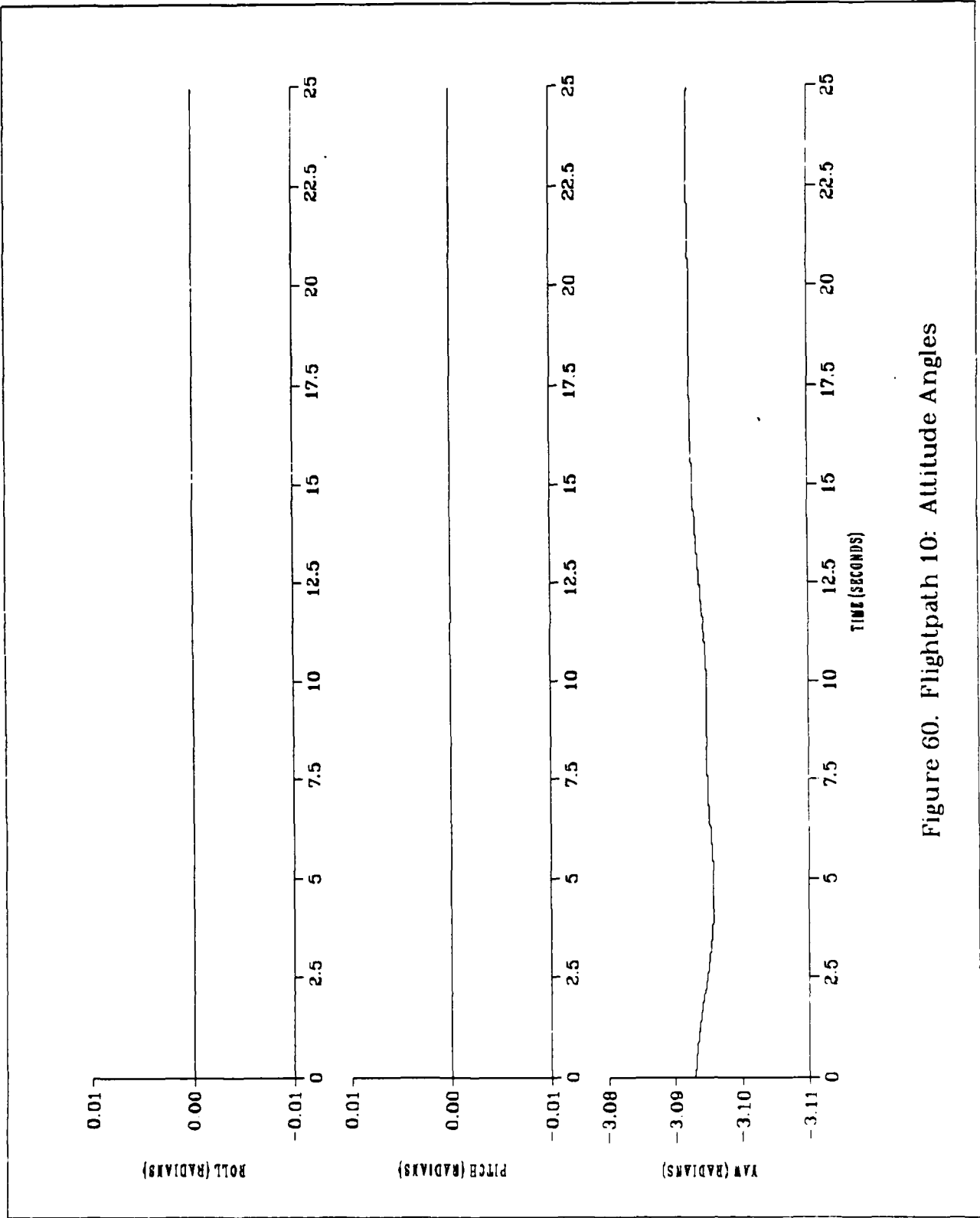
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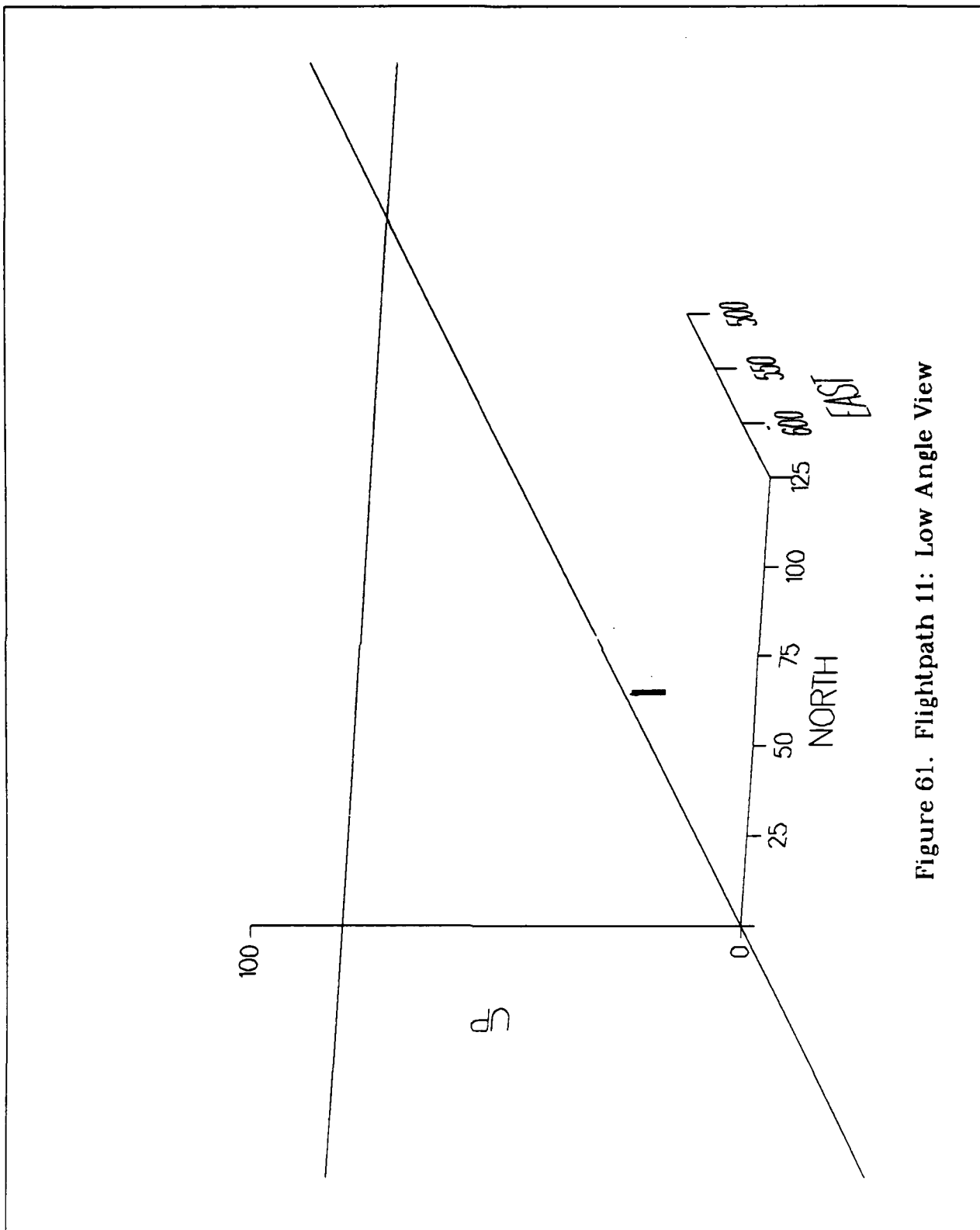
Figure 66. Flightpath 11: Attitude Angles

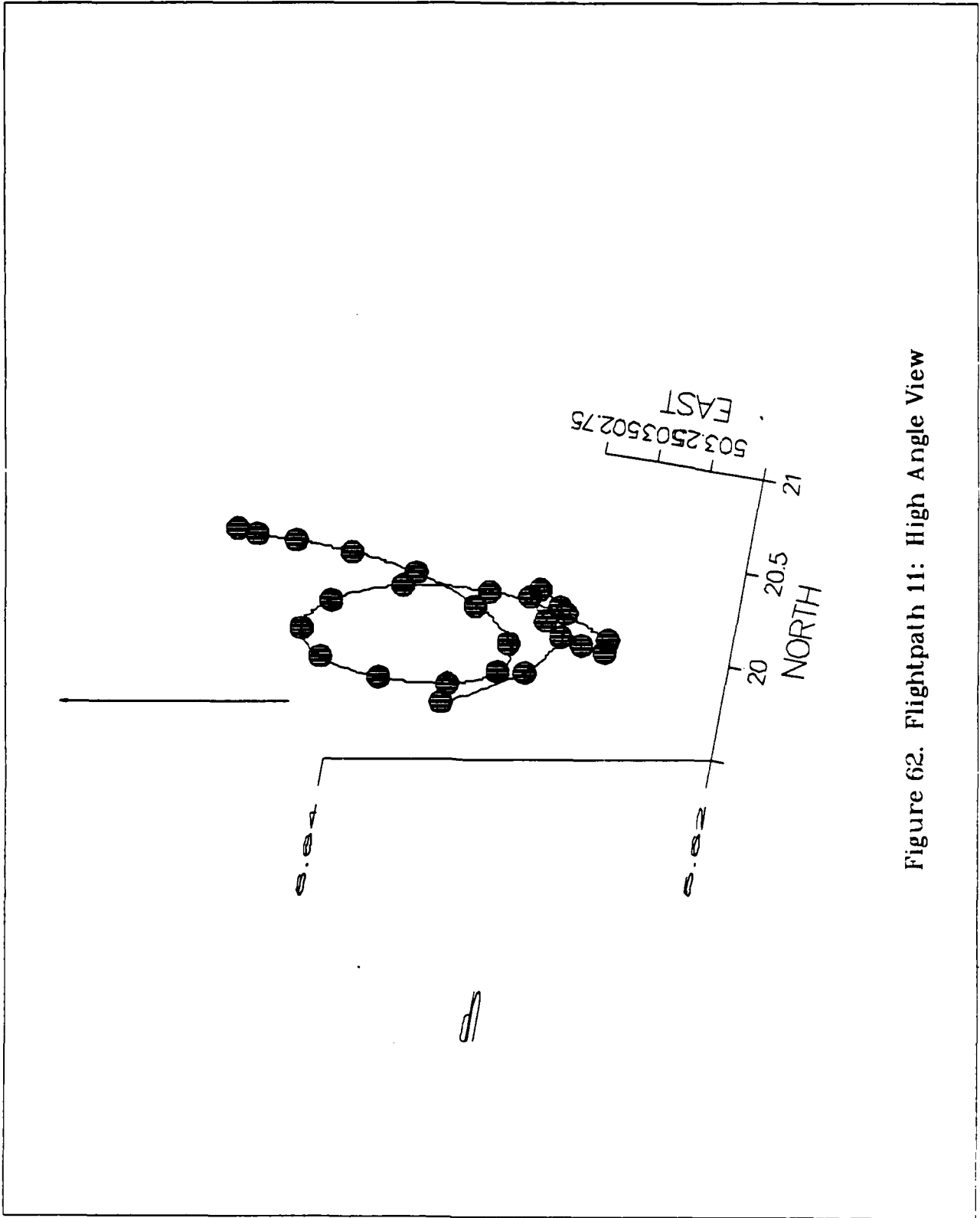Figure 67. Flightpath 12: Low Angle View
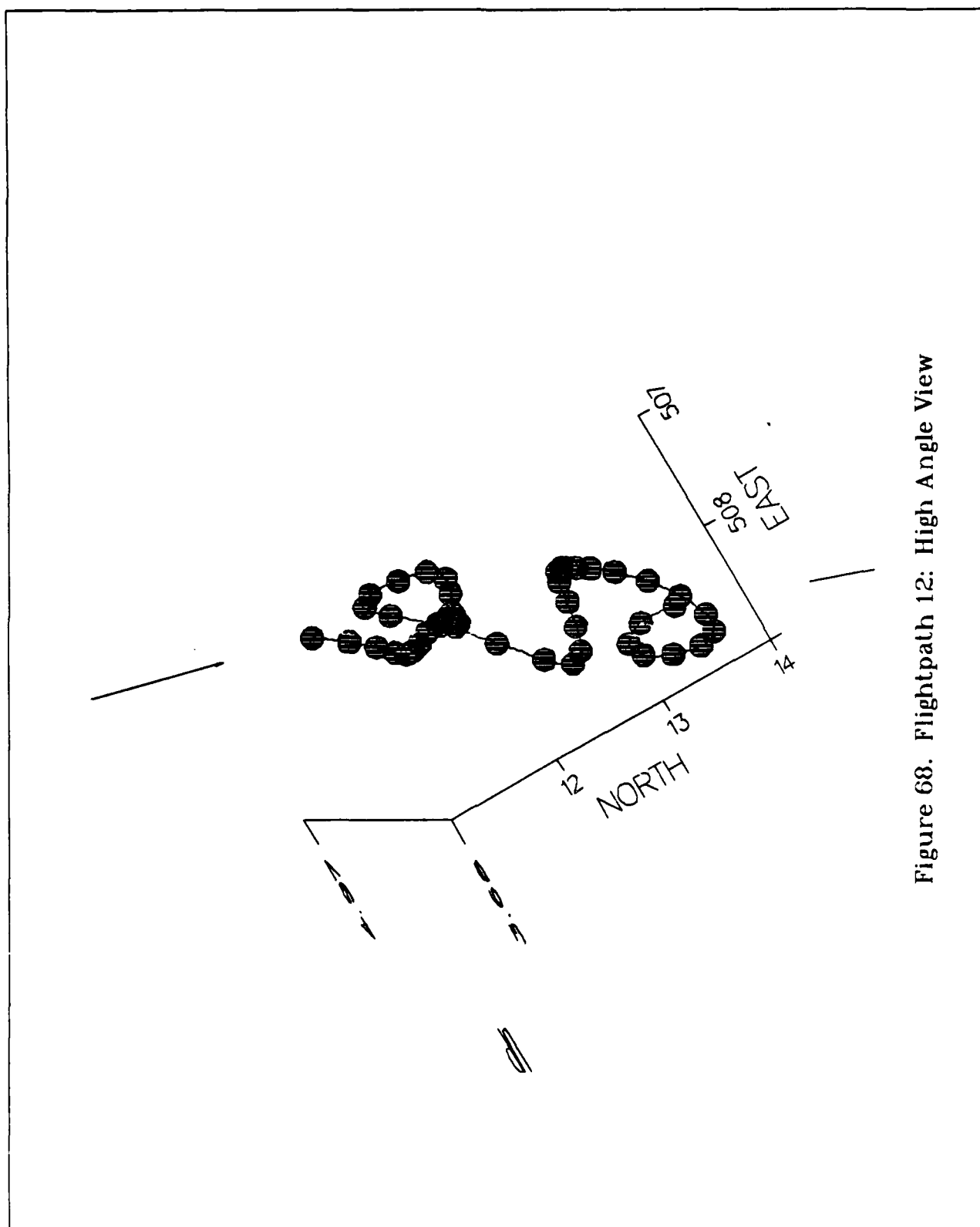
Figure 68. Flightpath 12: High Angle View

Figure 69. Flightpath 12: Position

Figure 70. Flightpath 12: Velocity

Figure 71. Flightpath 12: Acceleration

Figure 72. Flightpath 12: Altitude Angles

Figure 73. Flightpath 13: Low Angle View
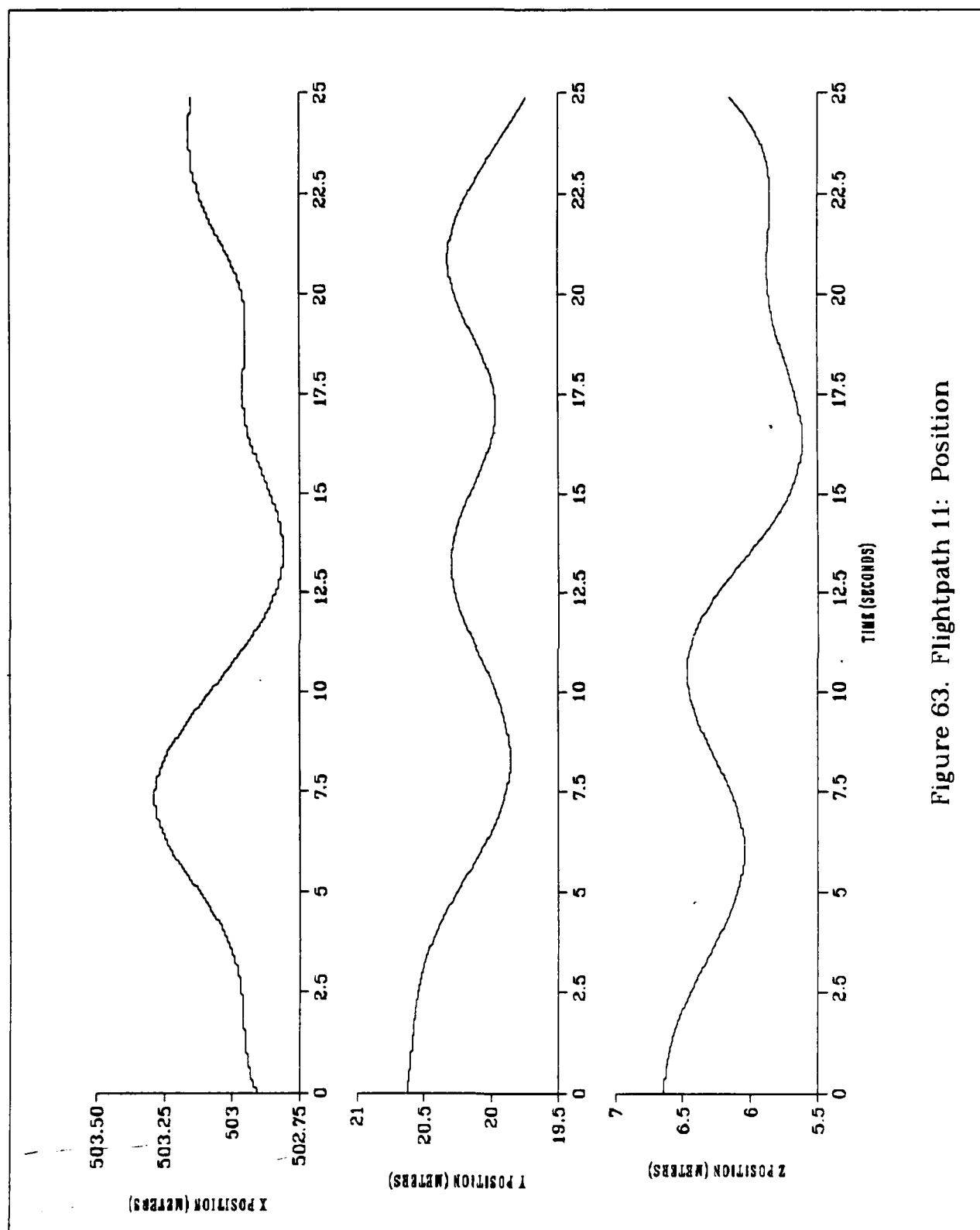
Figure 74. Flightpath 13: High Angle View
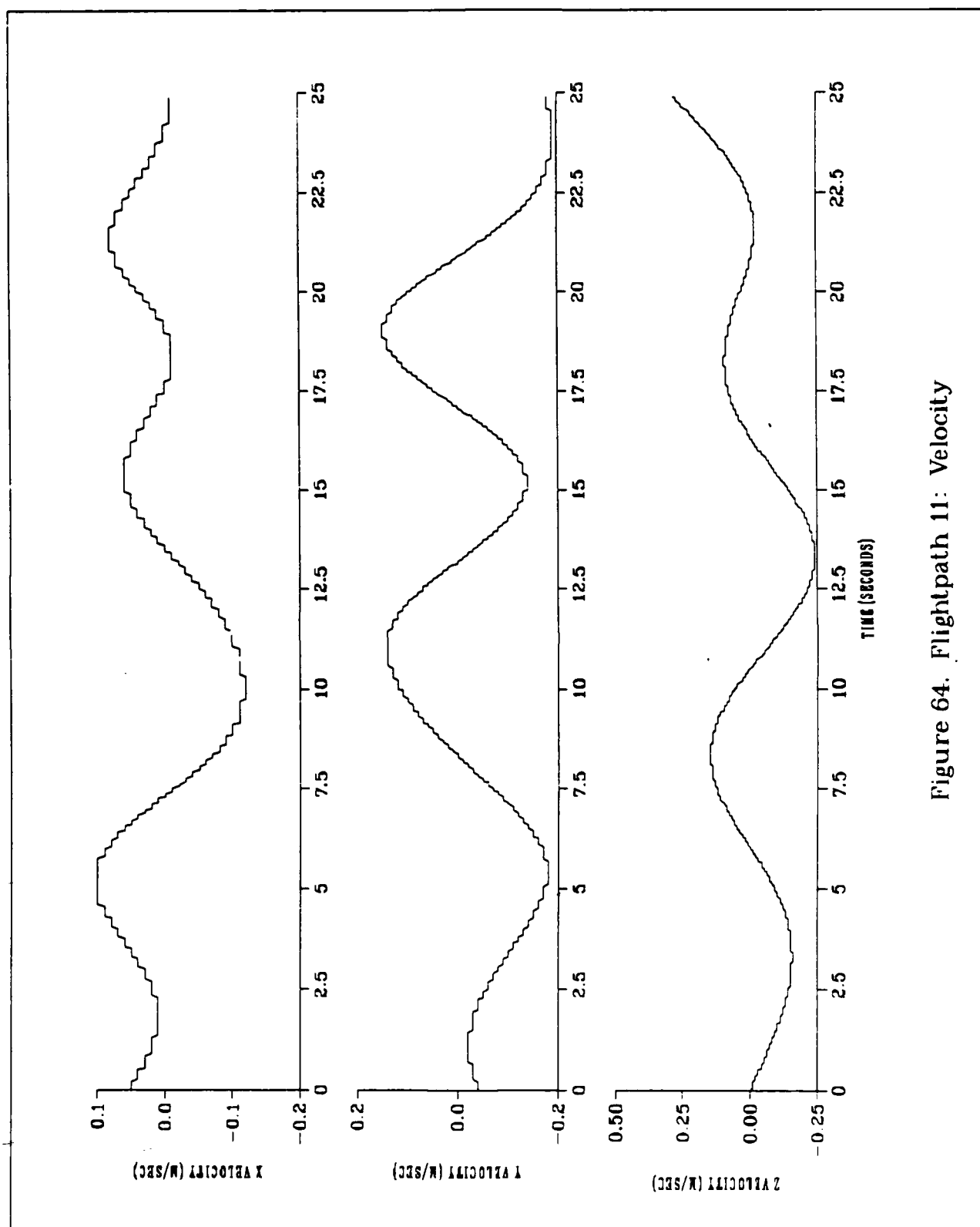
Figure 75. Flightpath 13: Position
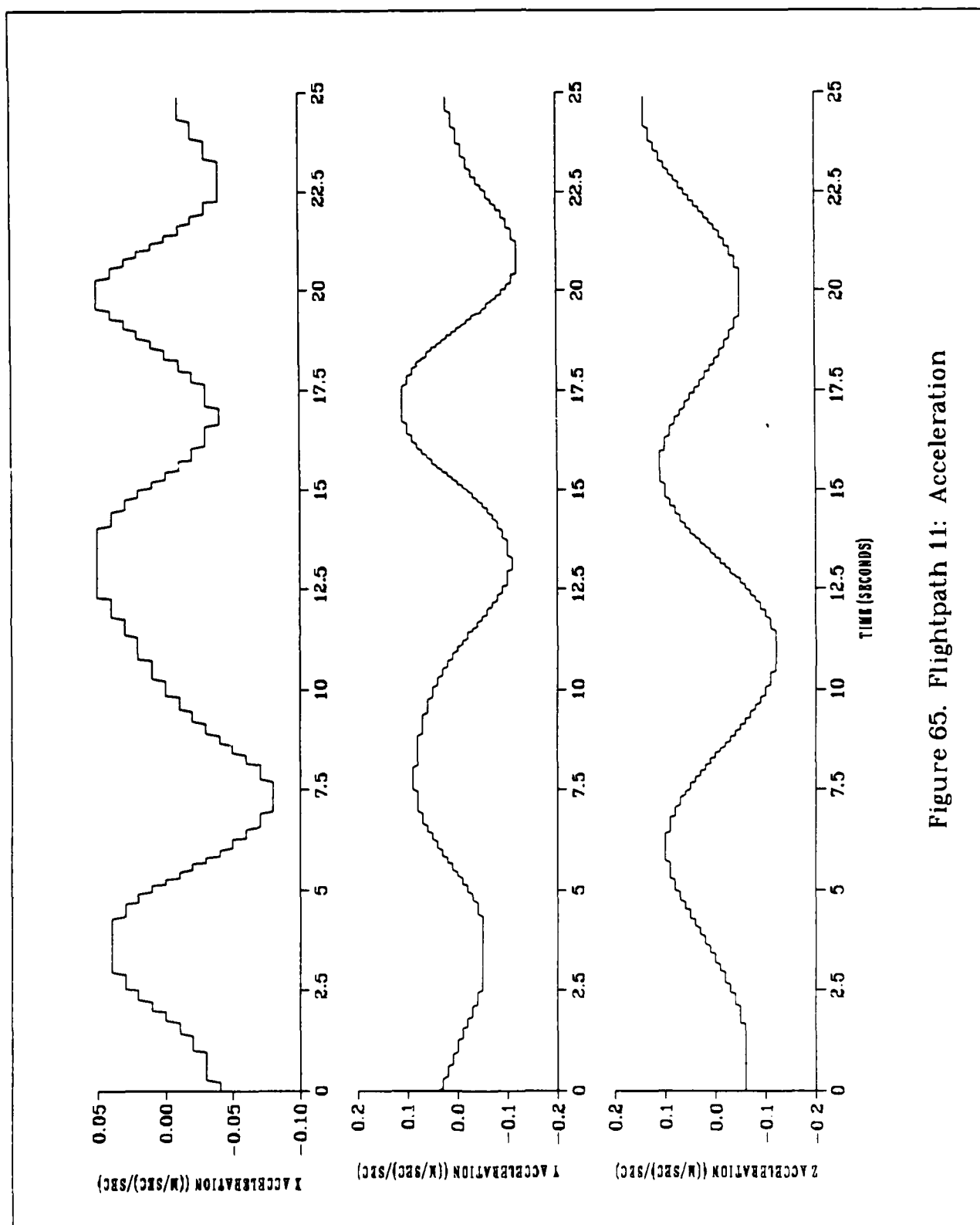
Figure 76. Flightpath 13: Velocity

Figure 77. Flightpath 13: Acceleration

Figure 78. Flightpath 13: Attitude Angles

Figure 79.  Flightpath 14:  Low Angle View

Figure 80. Flightpath 14: High Angle View

Figure 81. Flightpath 14: Position

Figure 82. Flightpath 14: Velocity

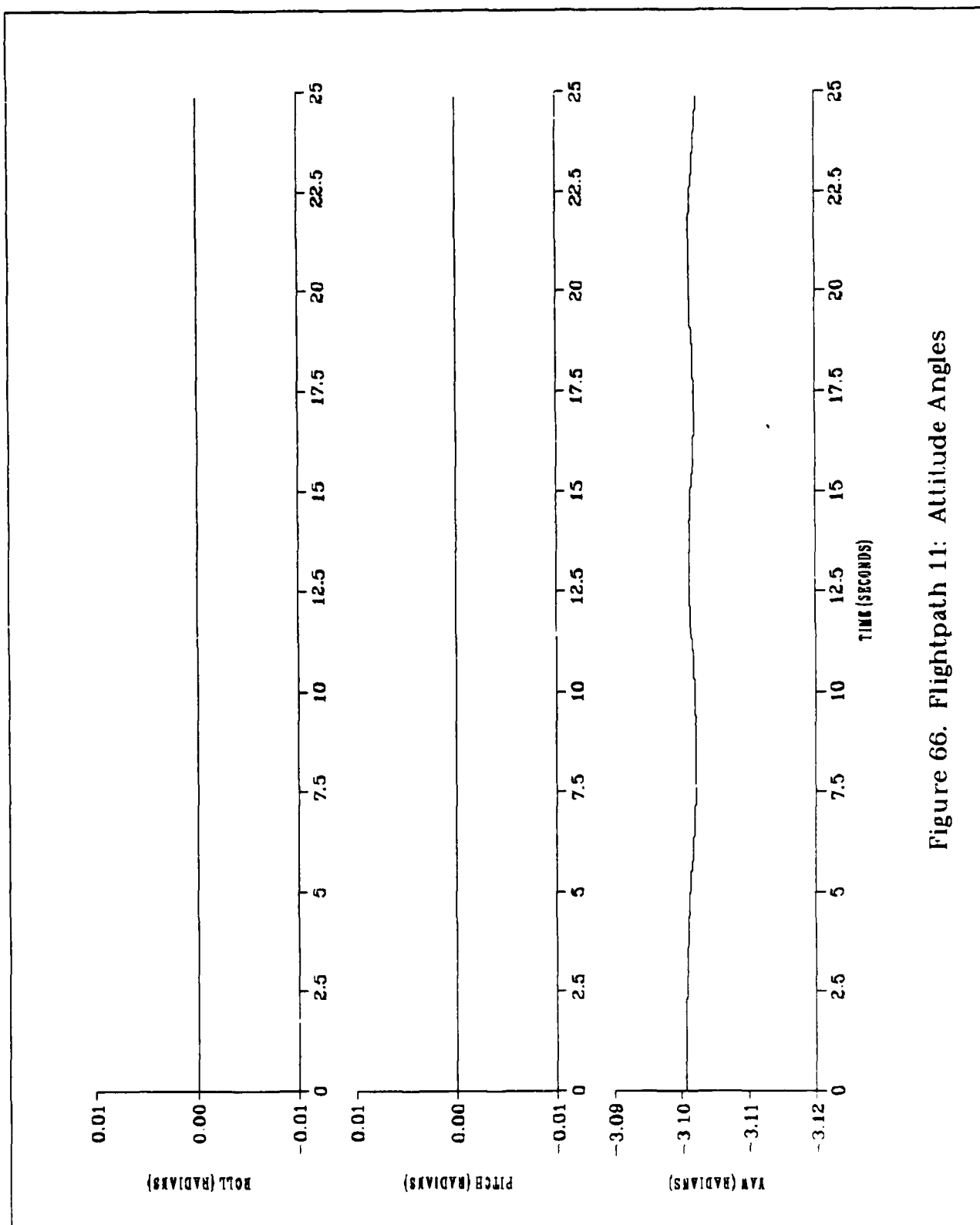Figure 83. Flightpath 14: Acceleration

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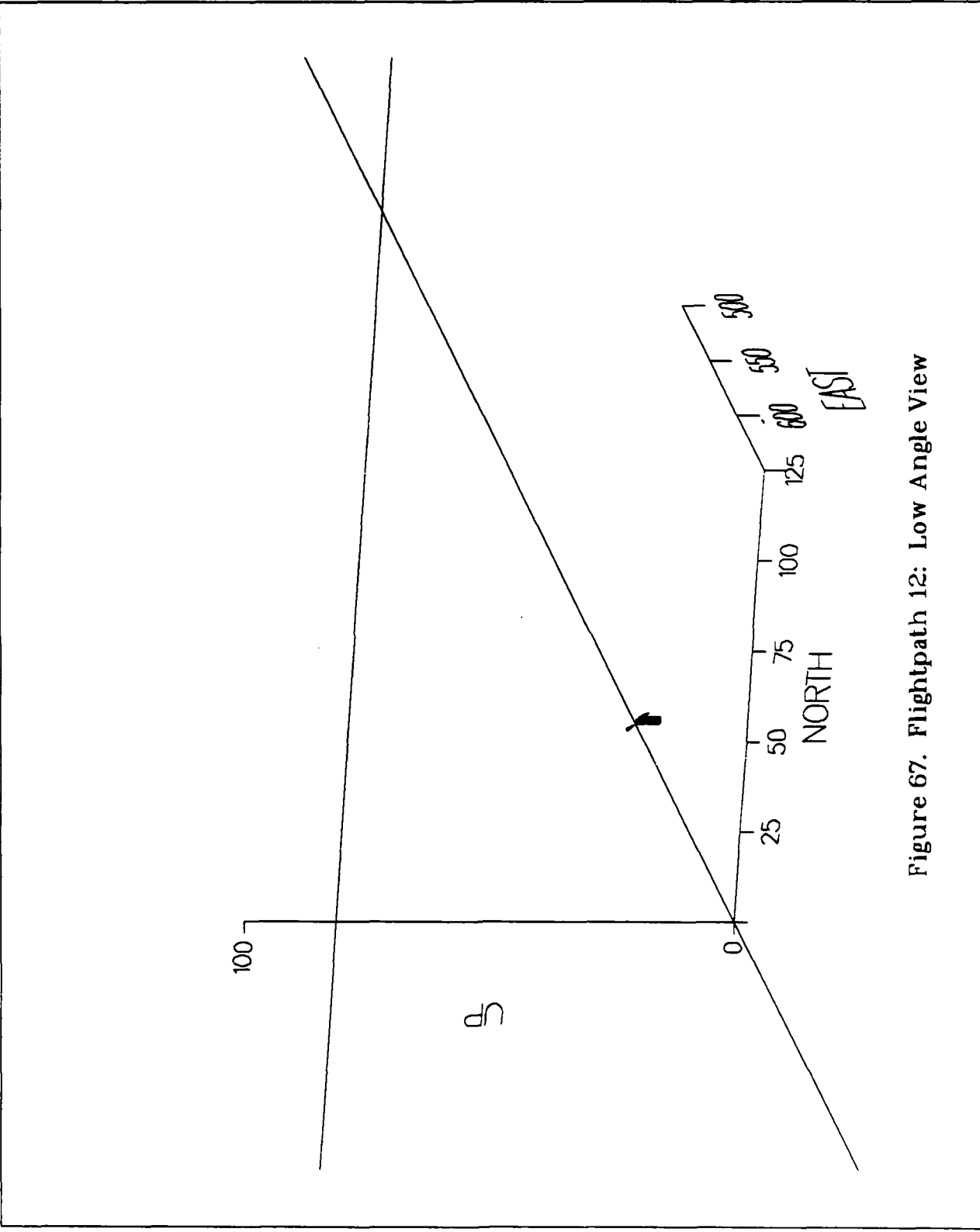Figure 84. Flightpath 14: Attitude Angles

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Figure 85. Flightpath 15: Low Angle View

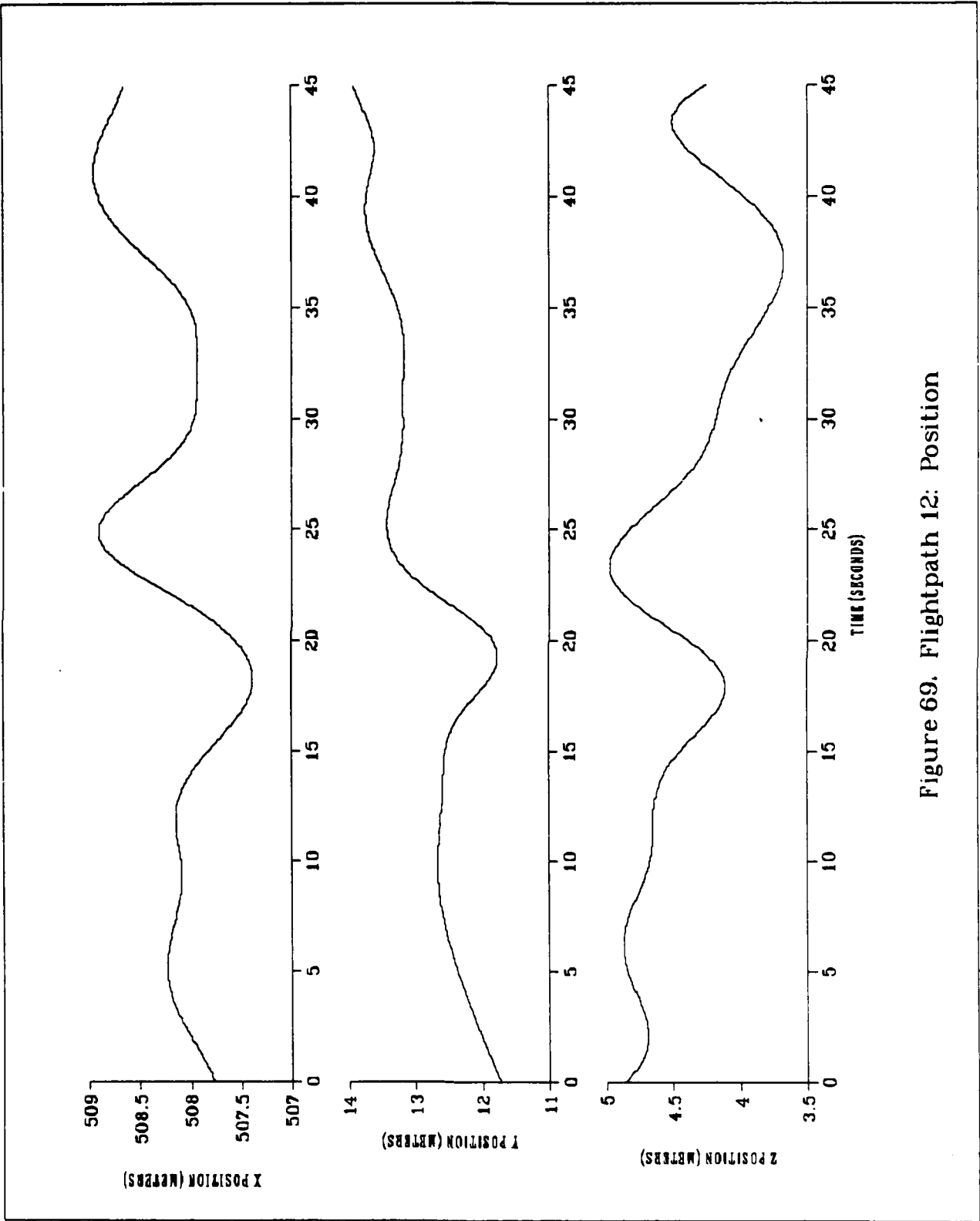Figure 86. Flightpath 15: High Angle View

Figure 87. Flightpath 15: Position

Figure 88. Flightpath 15: Velocity

Figure 89. Flightpath 15: Acceleration

Figure 90. Flightpath 15: Attitude Angles

Figure 91. Flightpath 16: Low Angle View
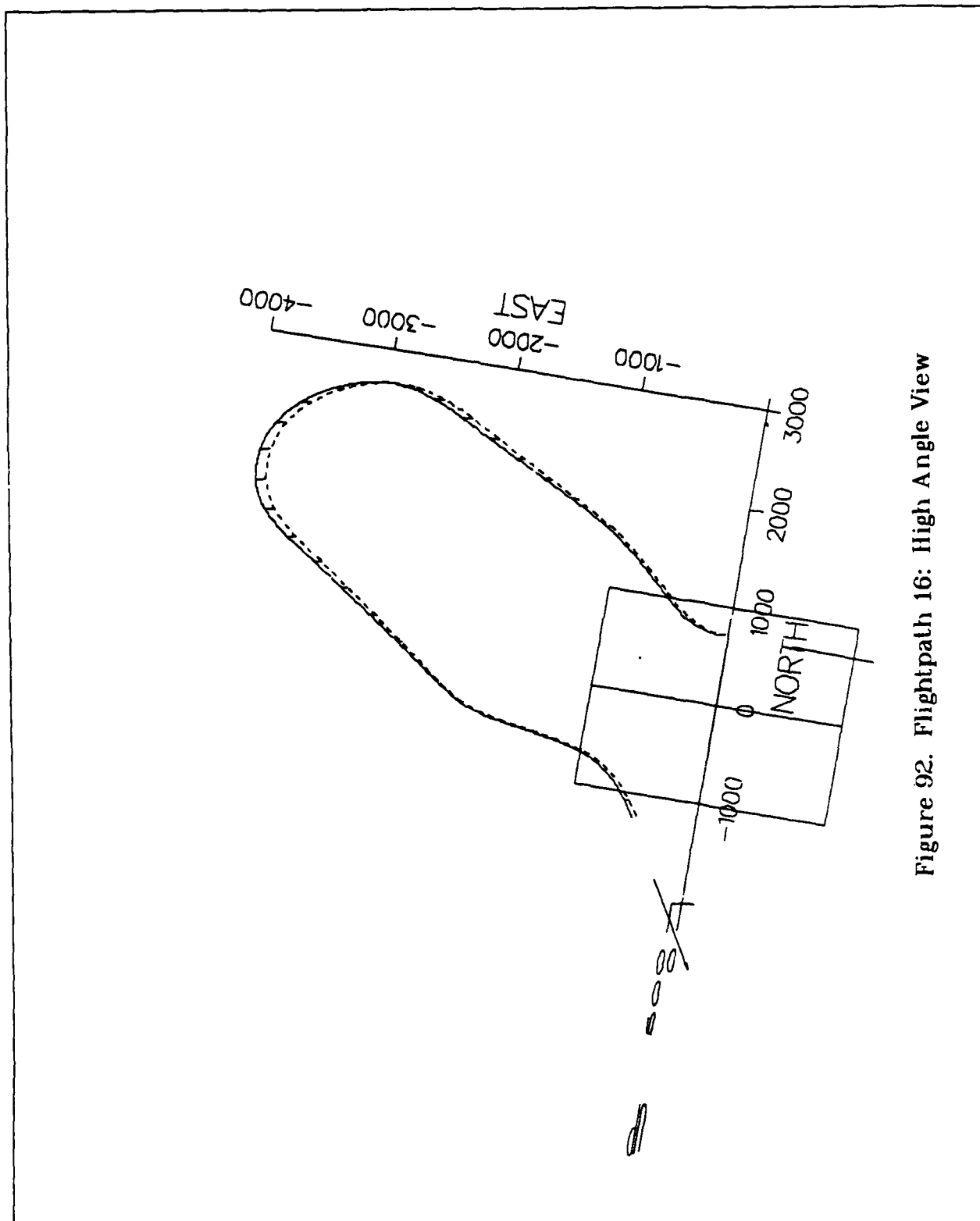
Figure 92. Flightpath 16: High Angle View
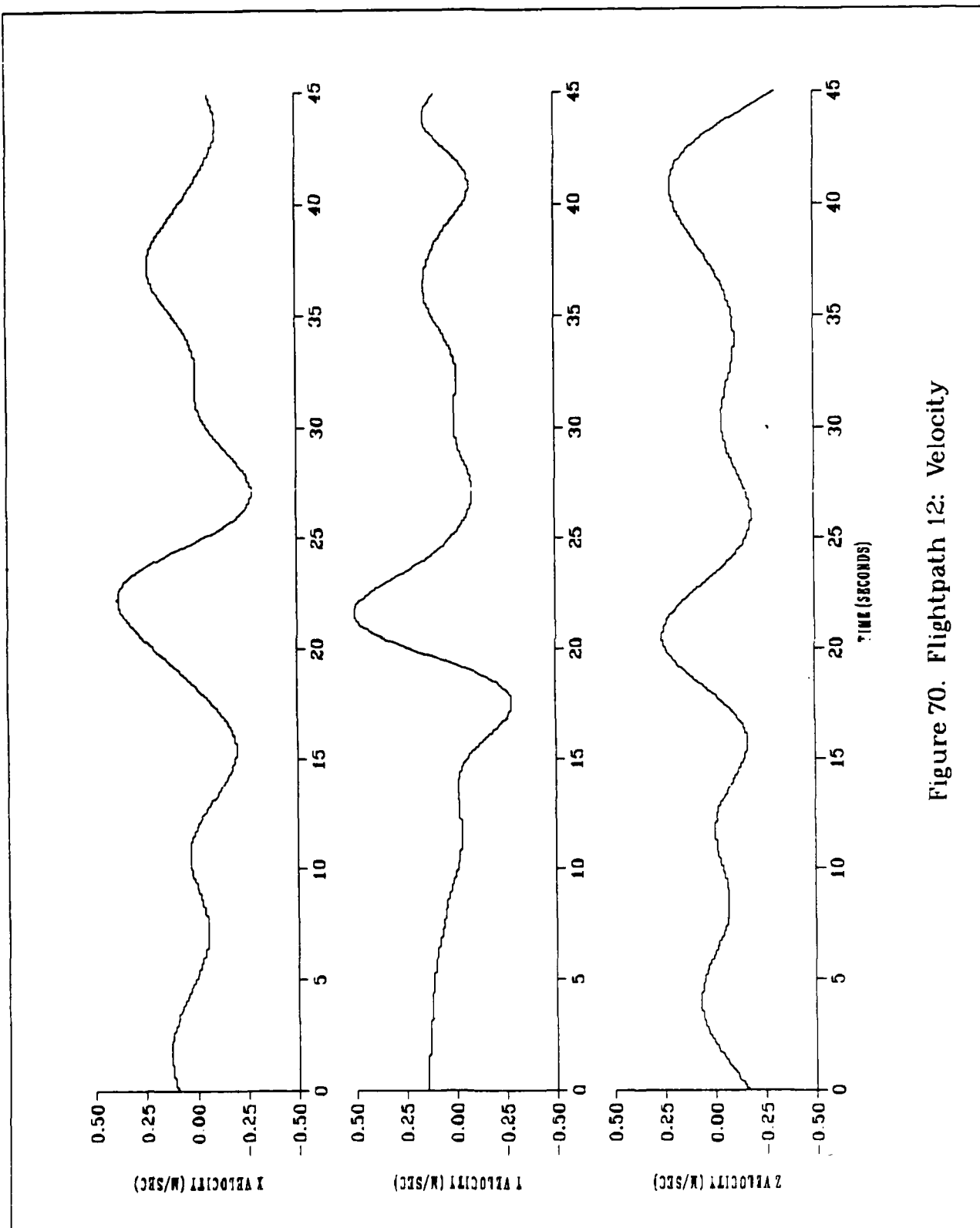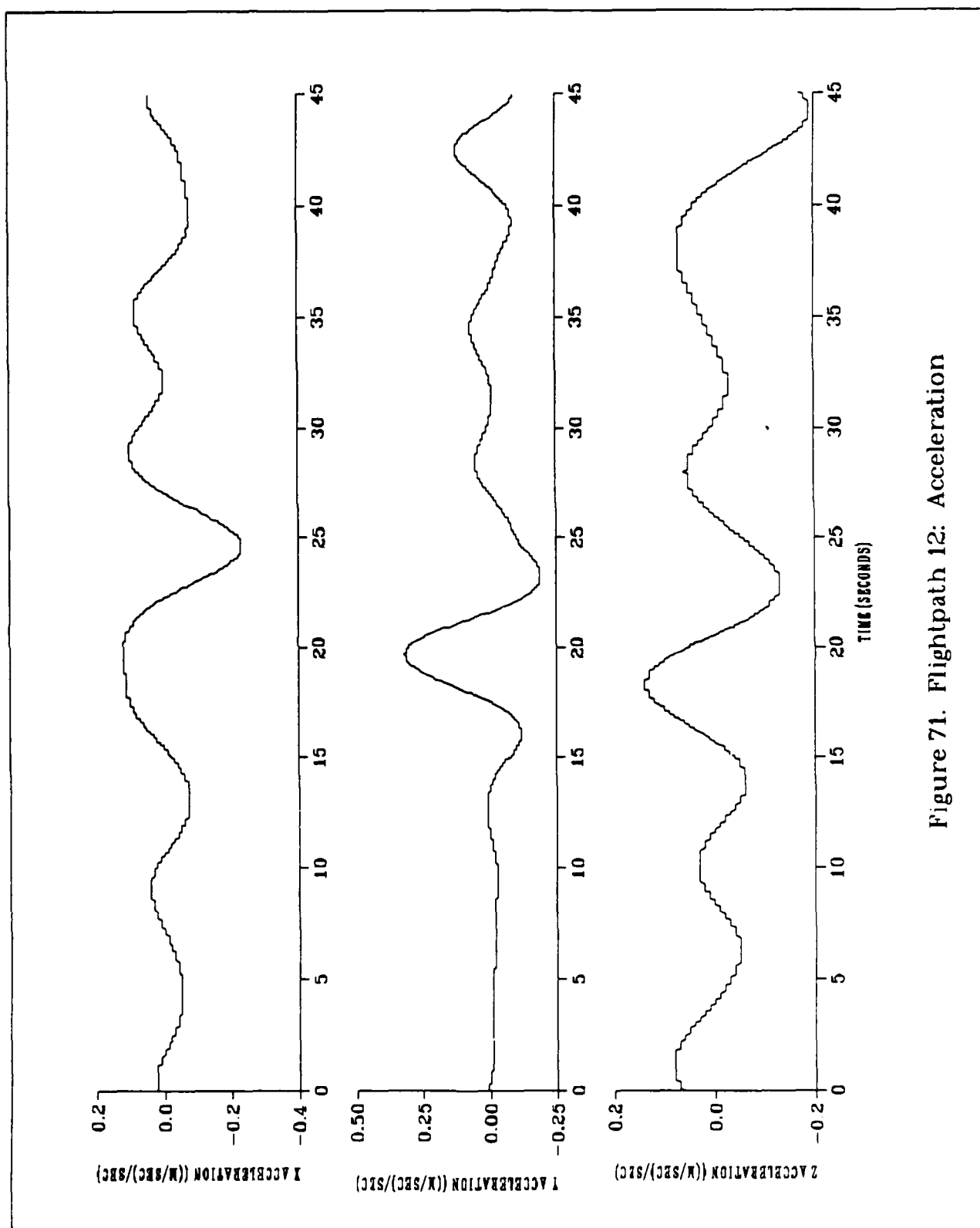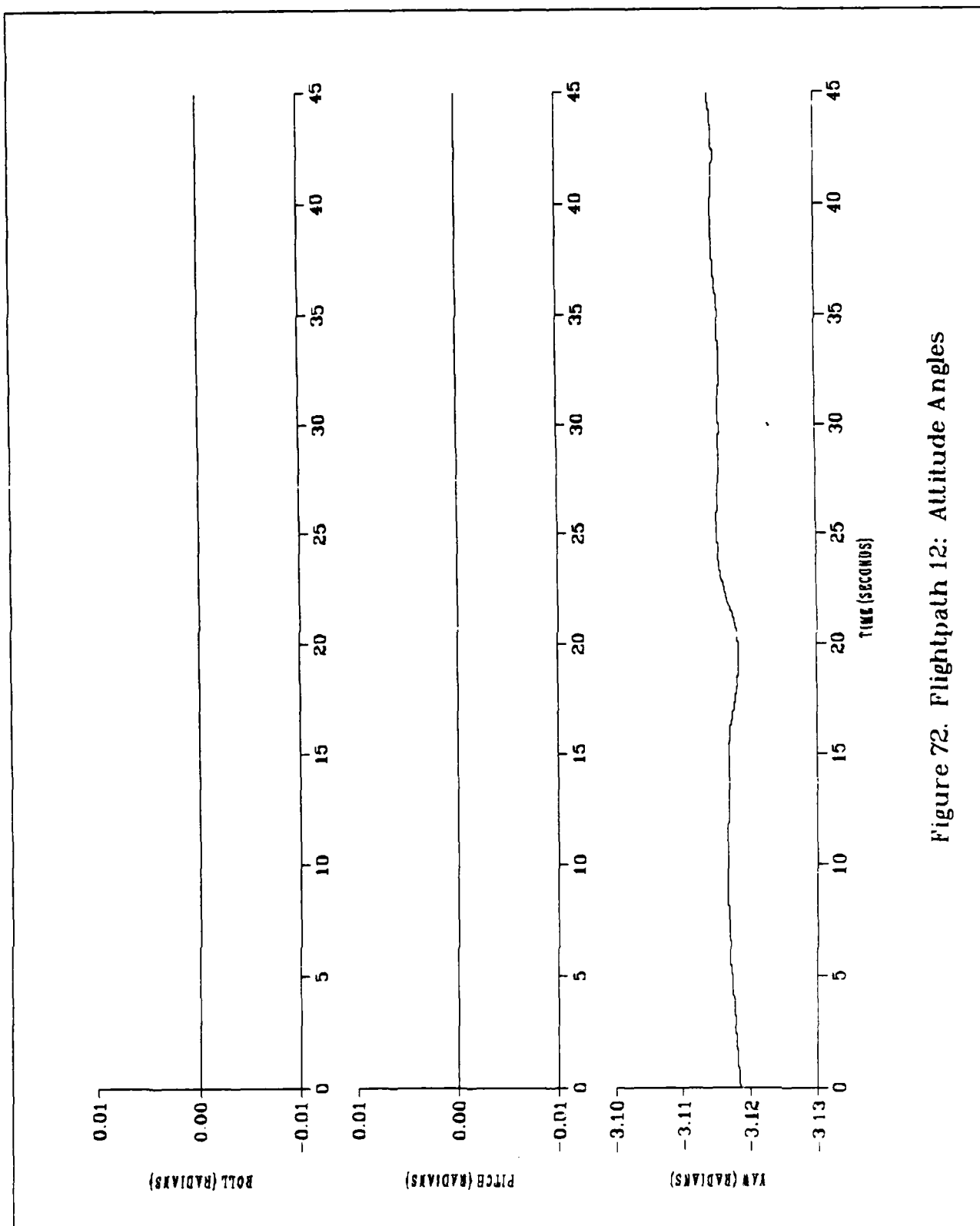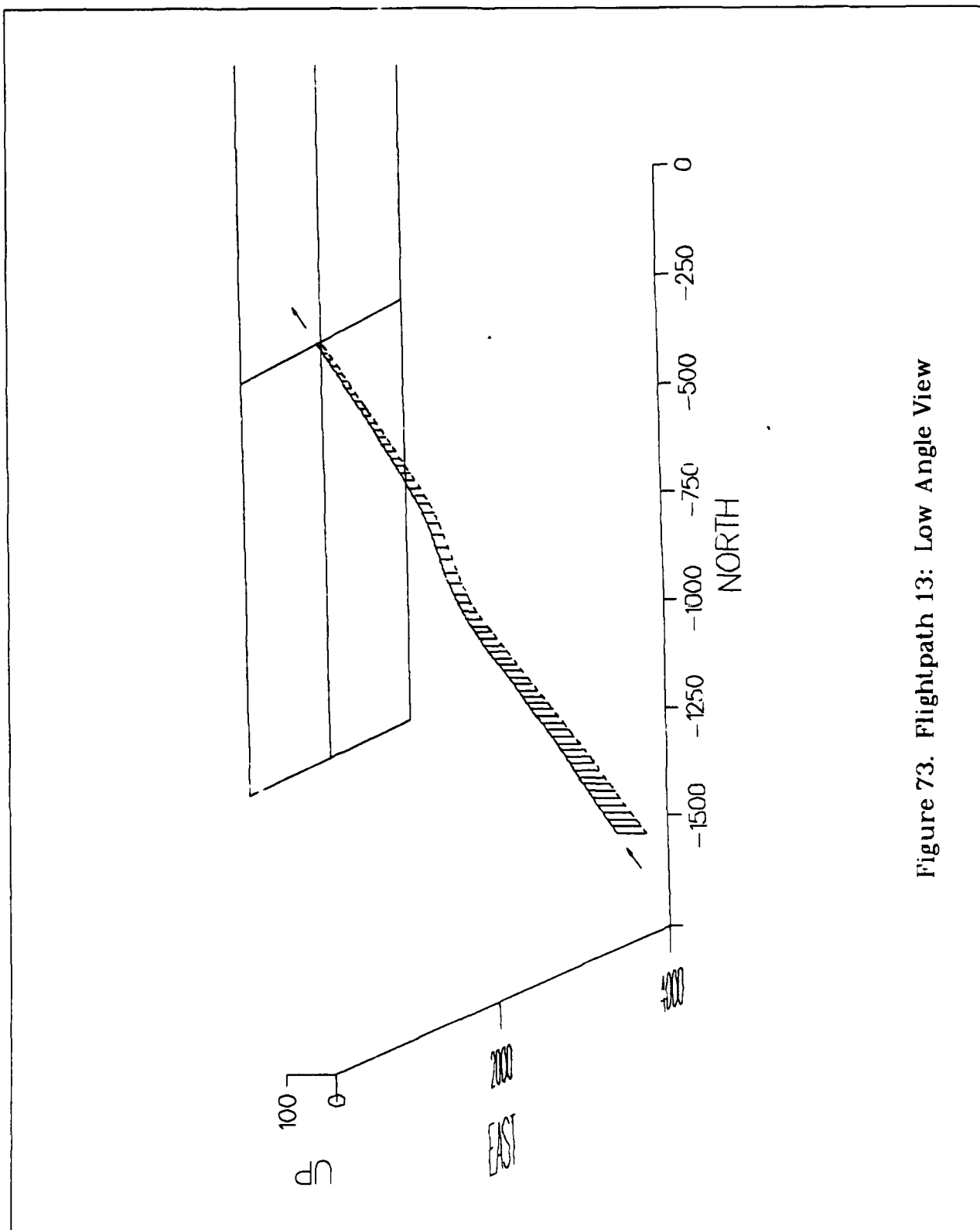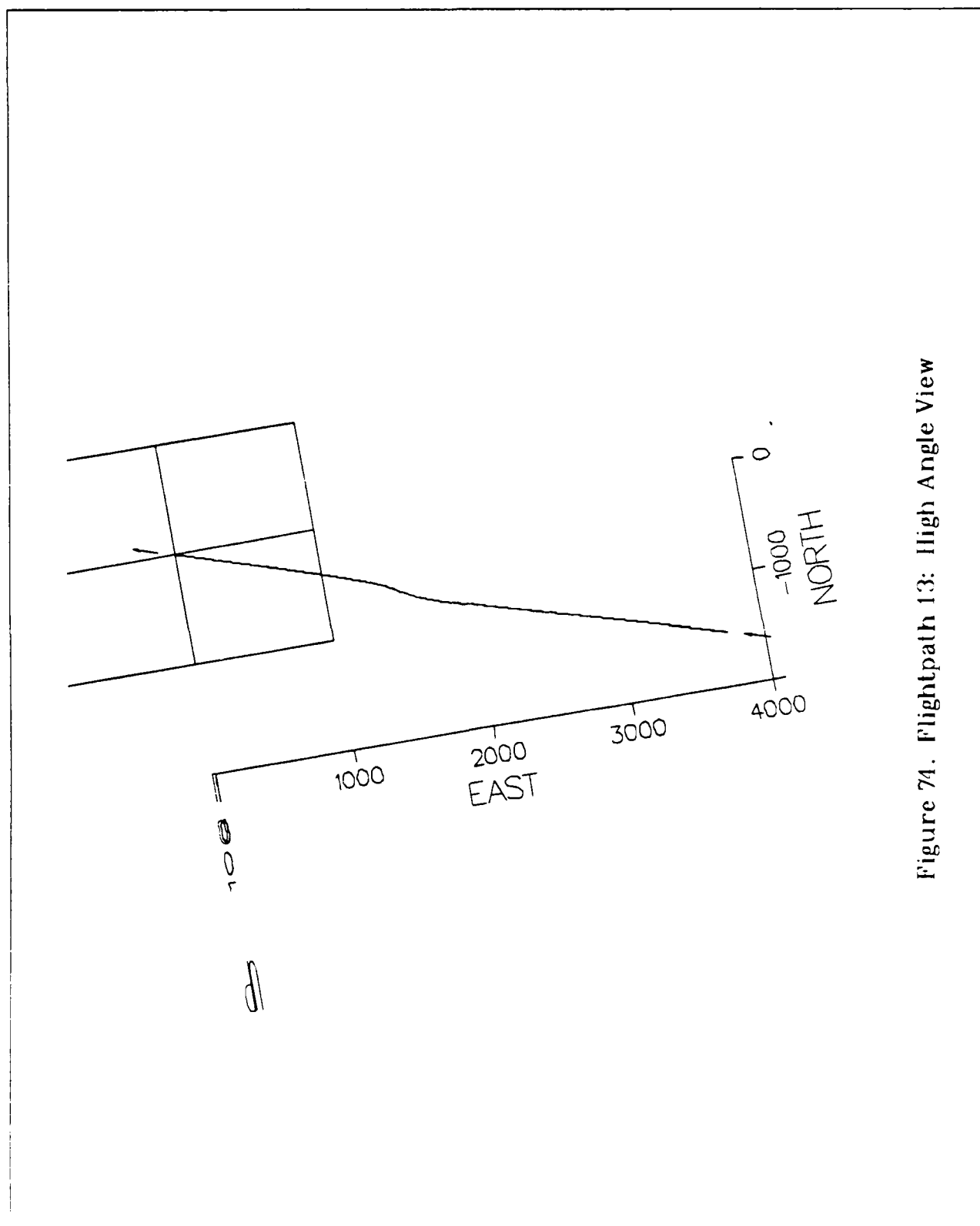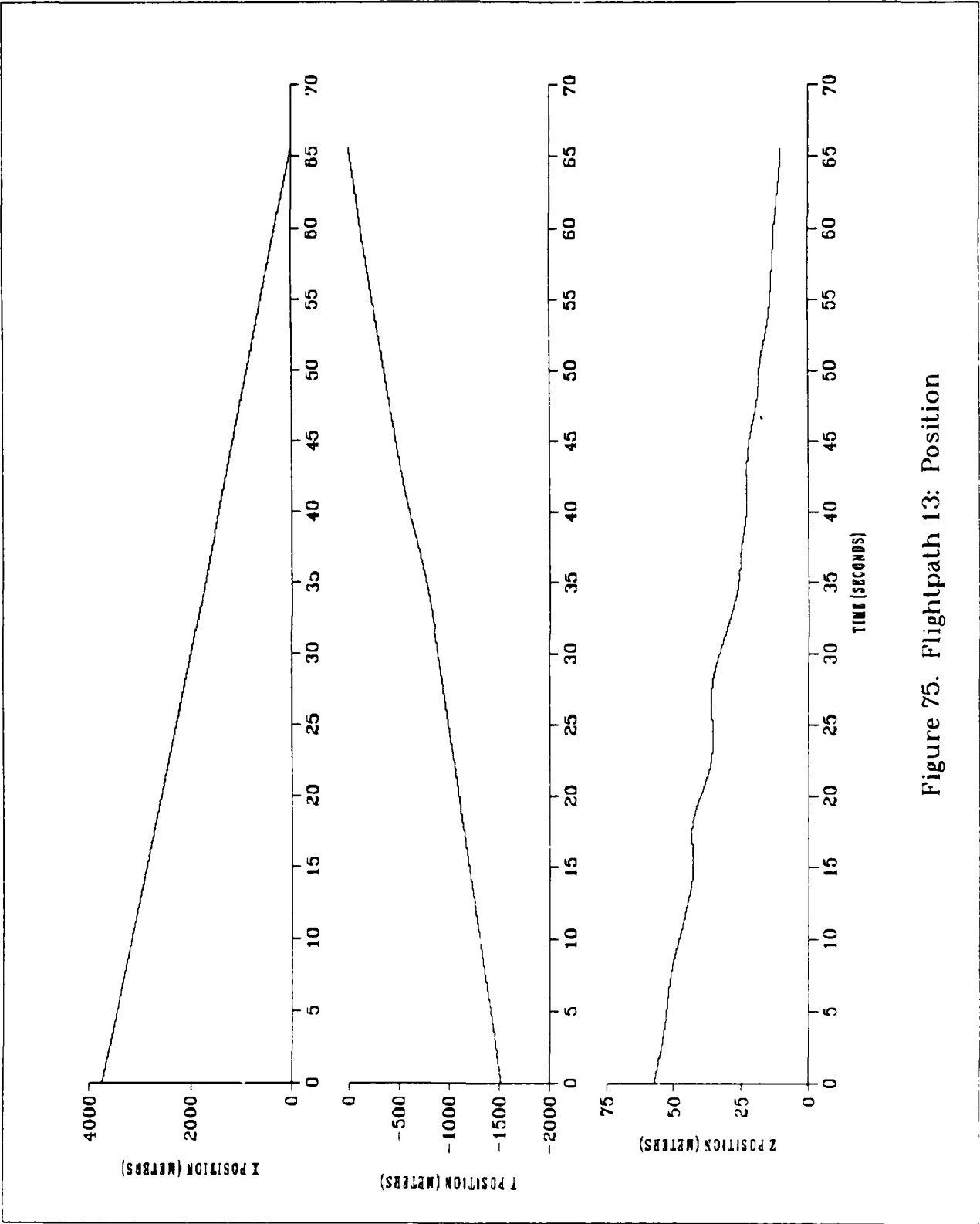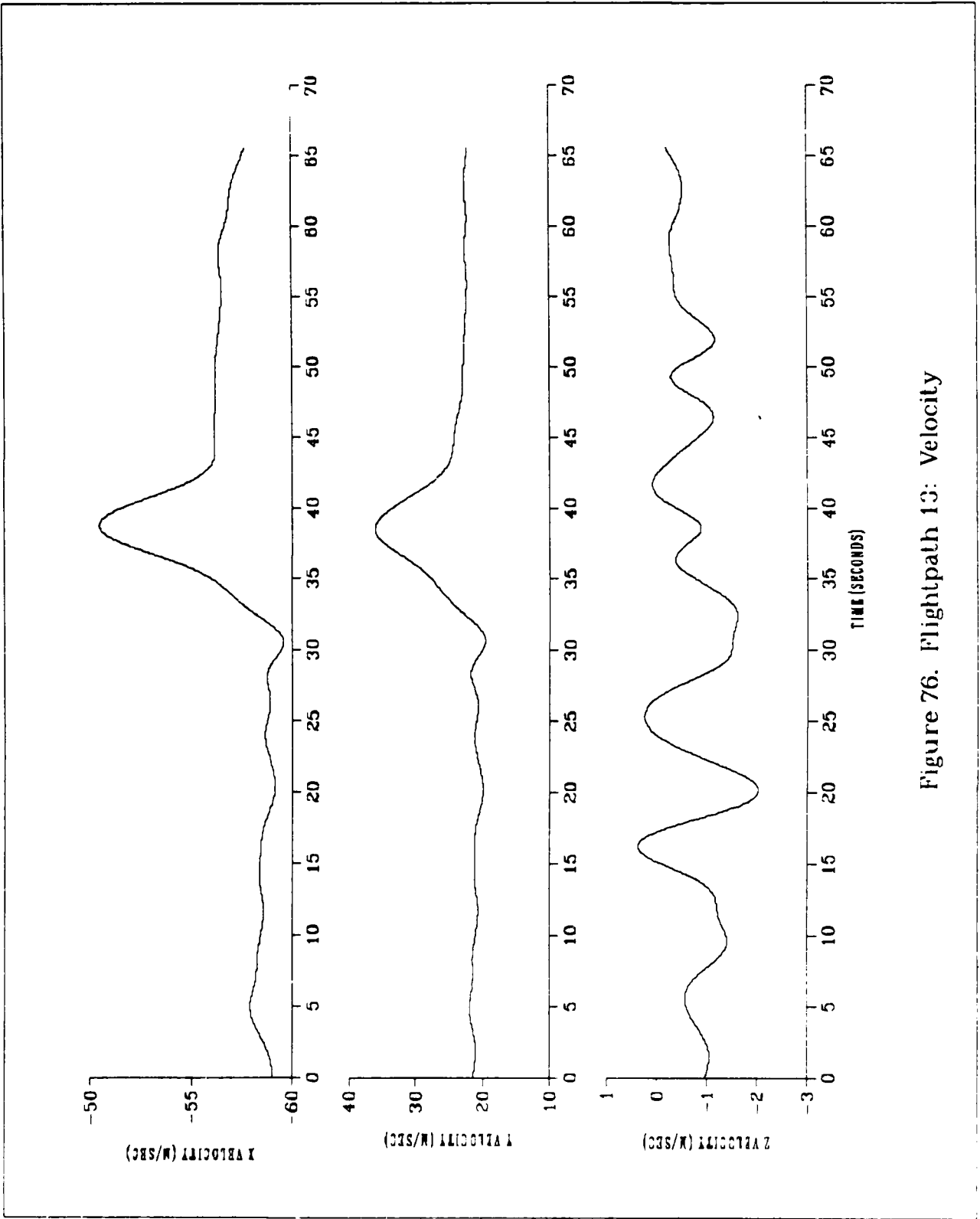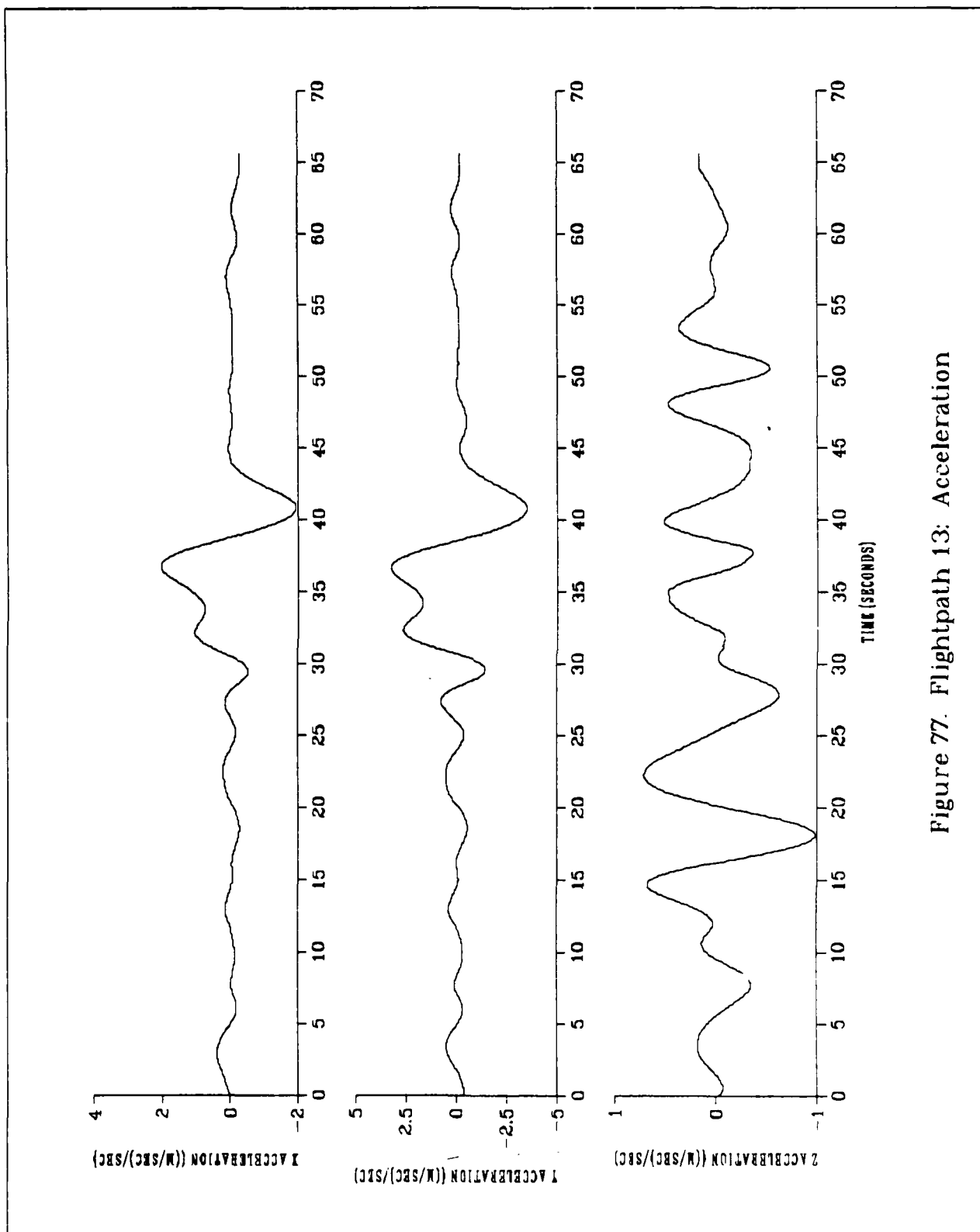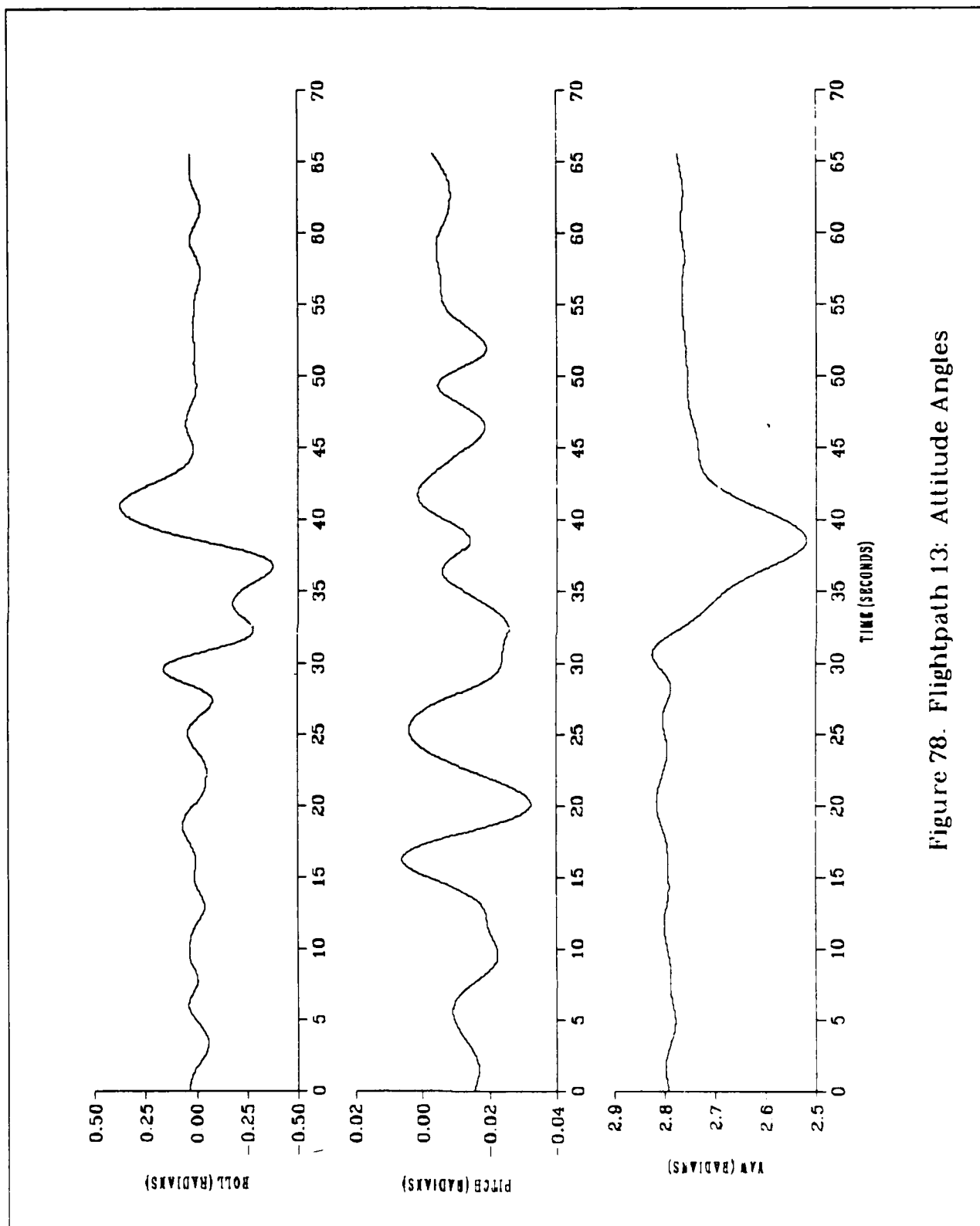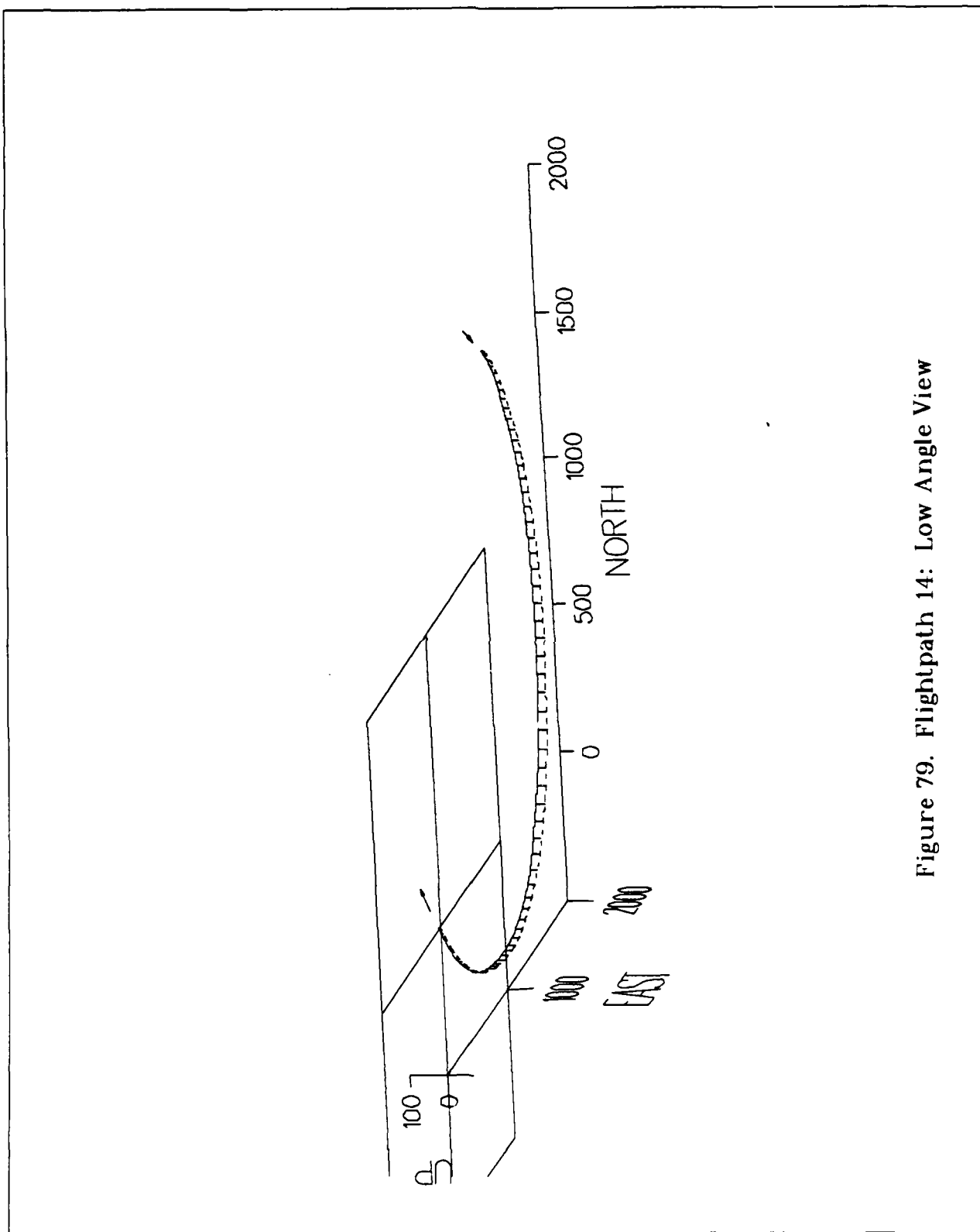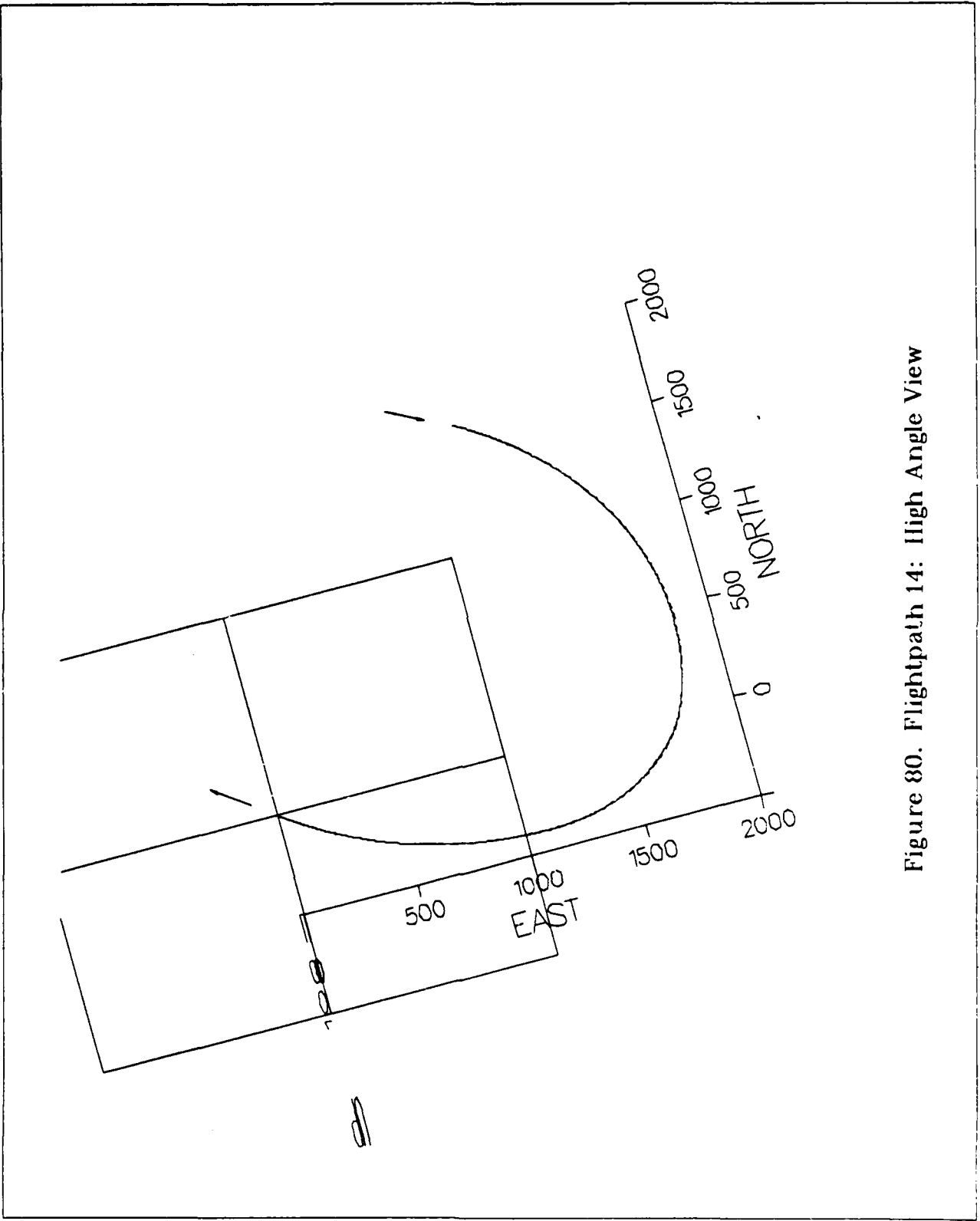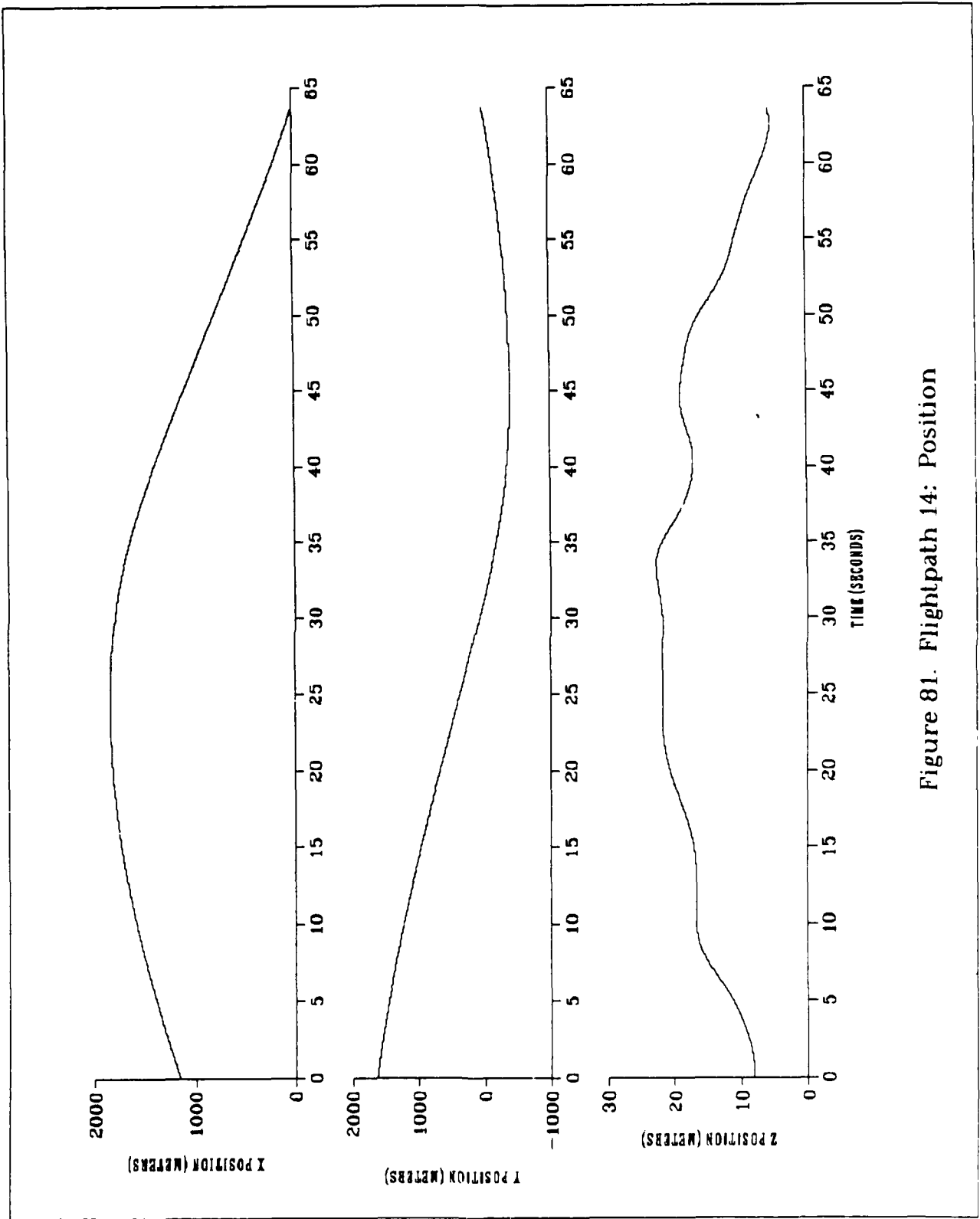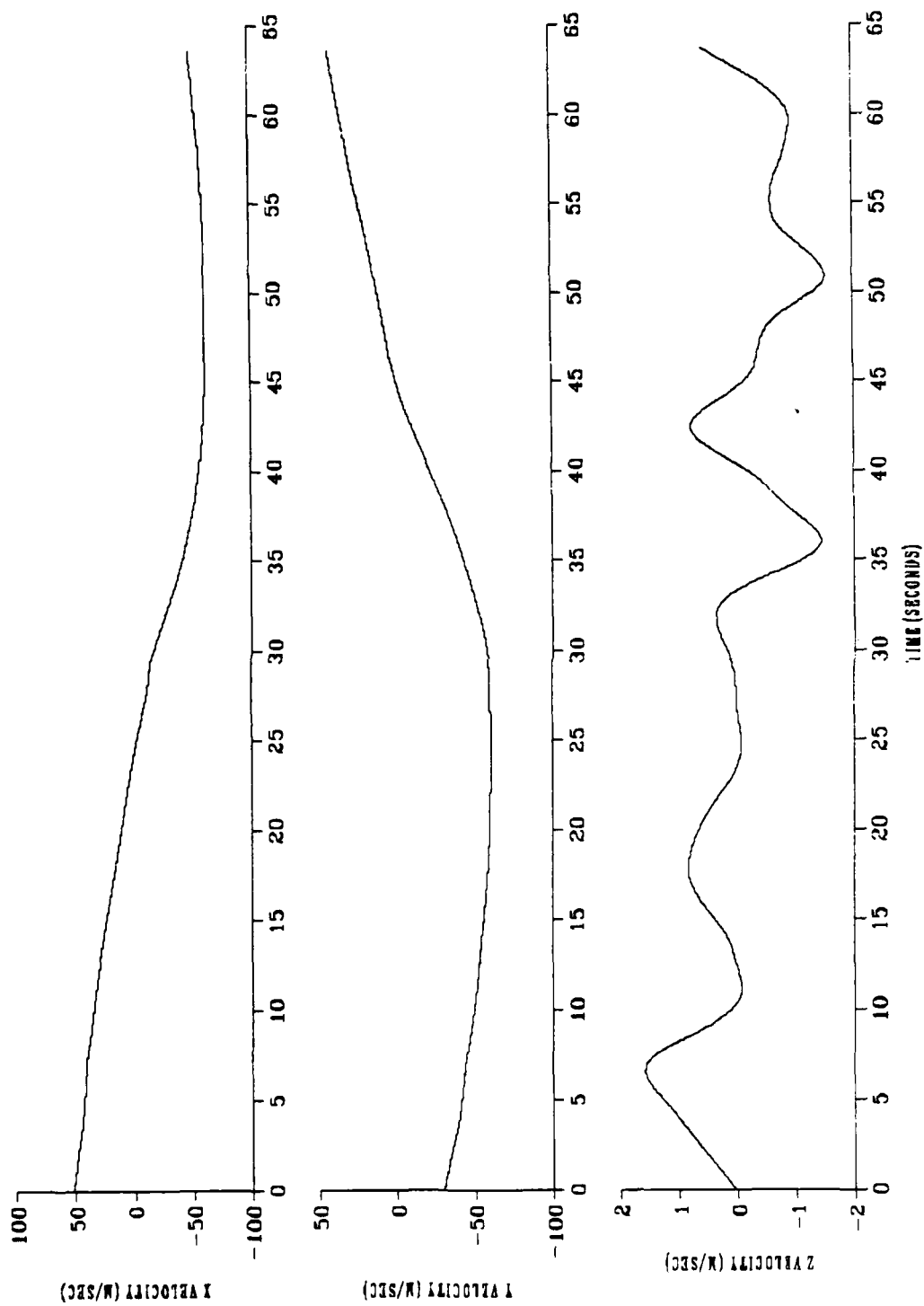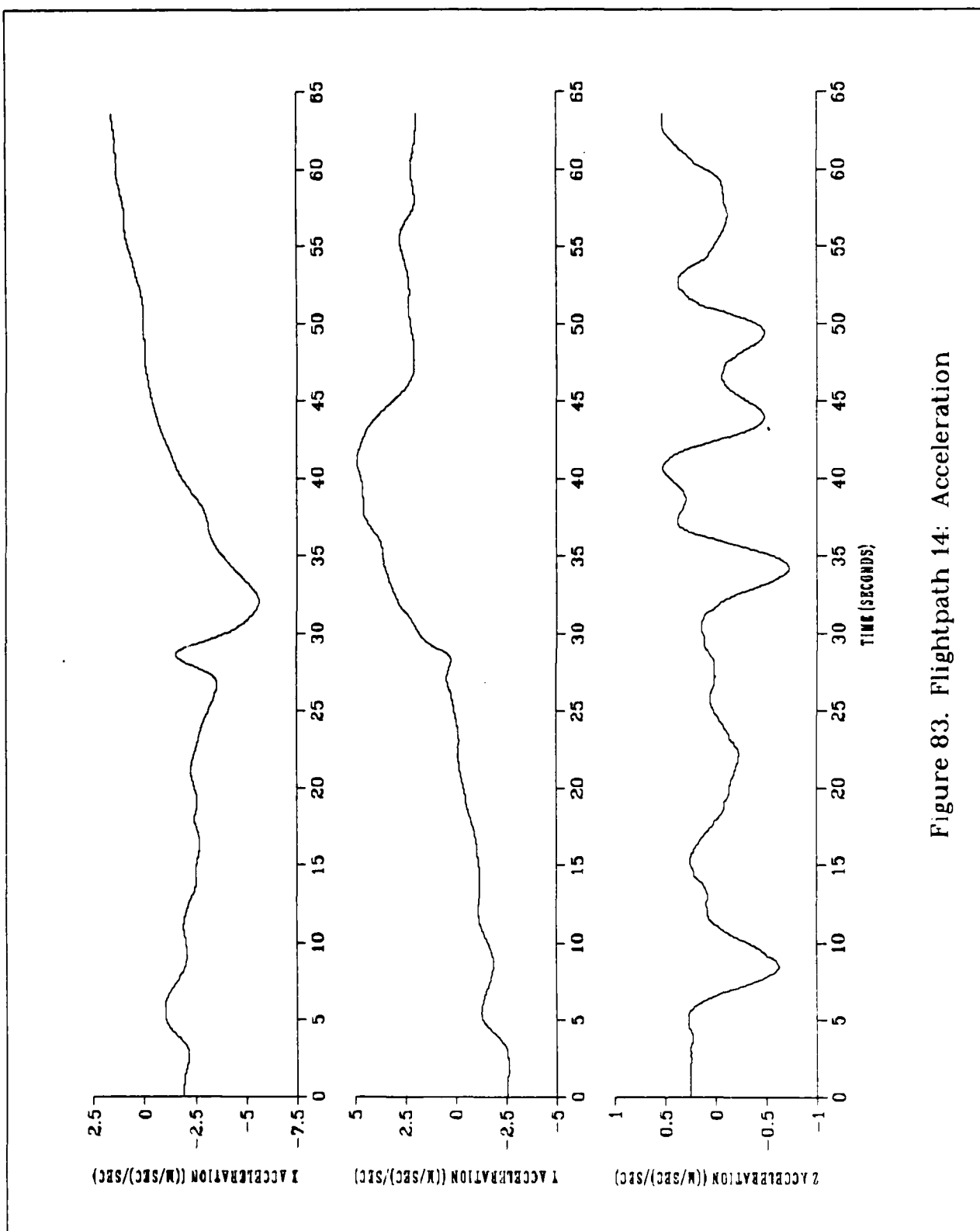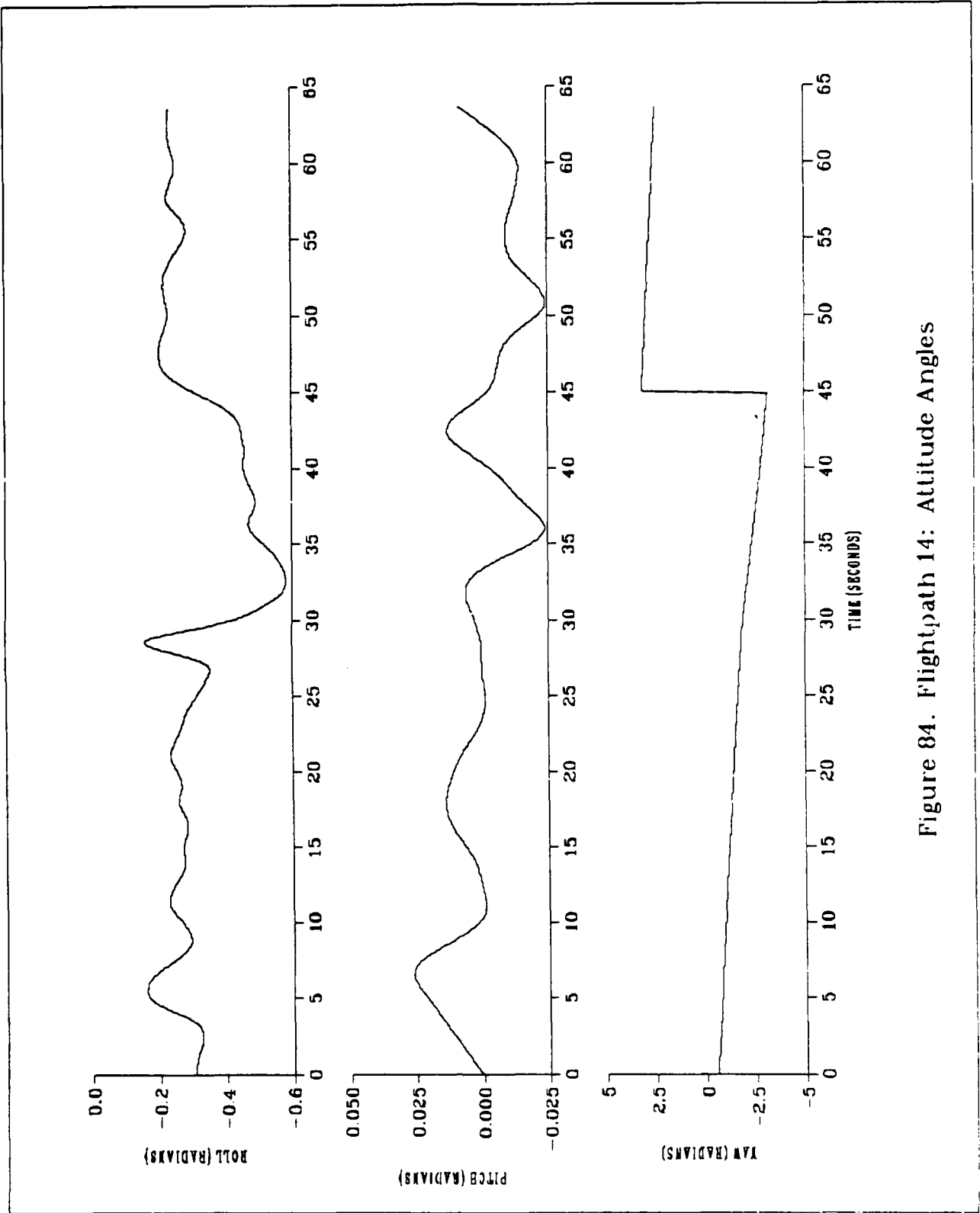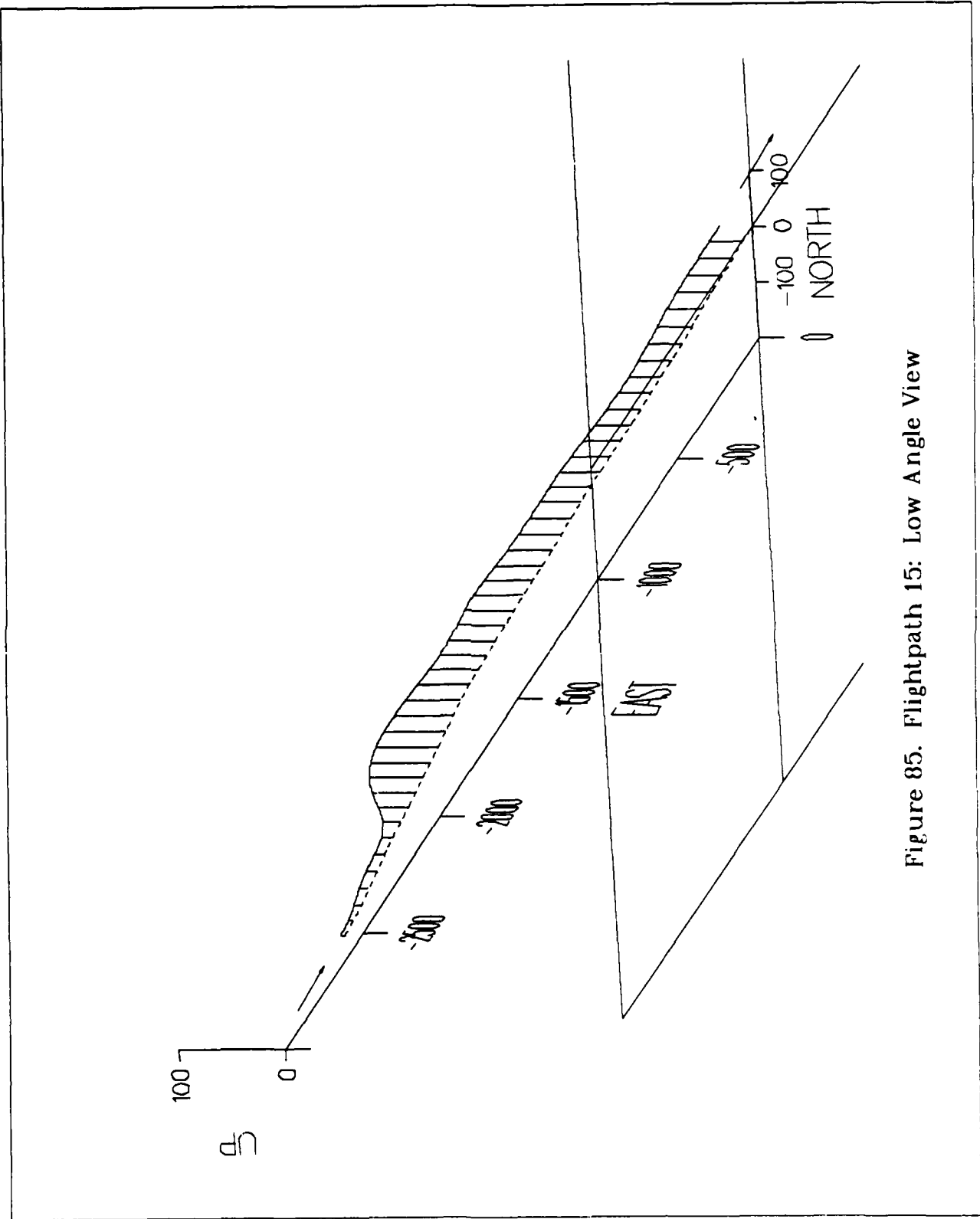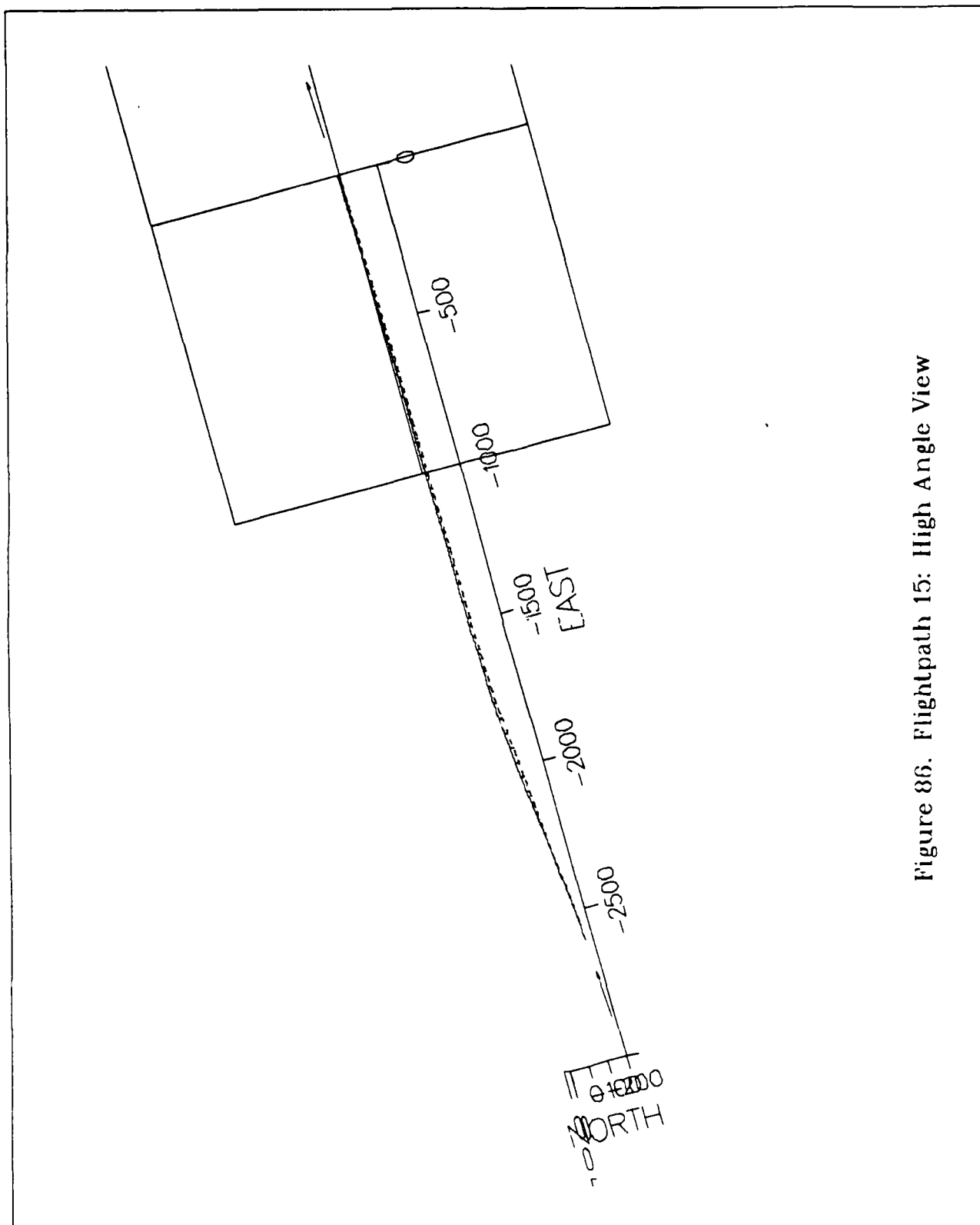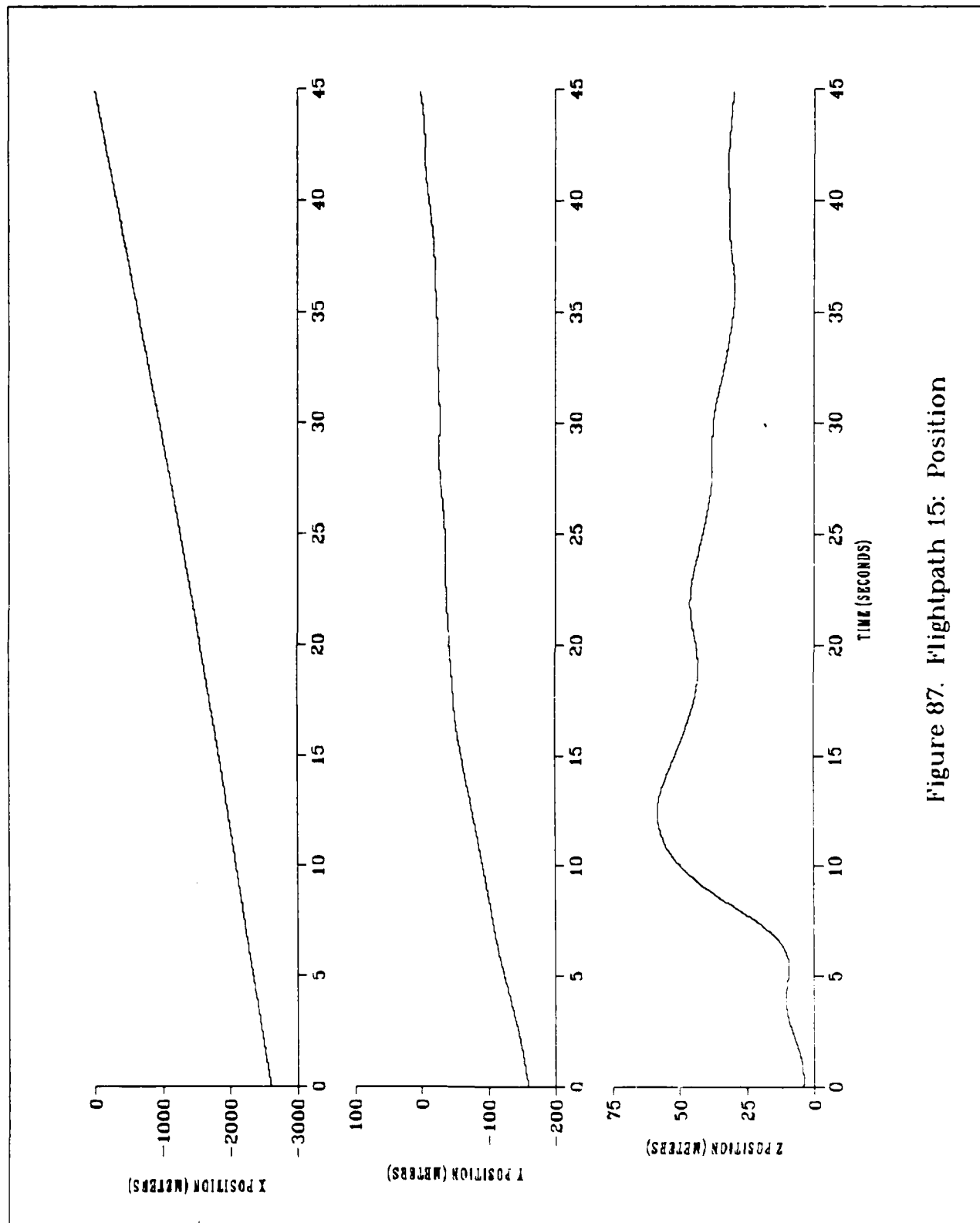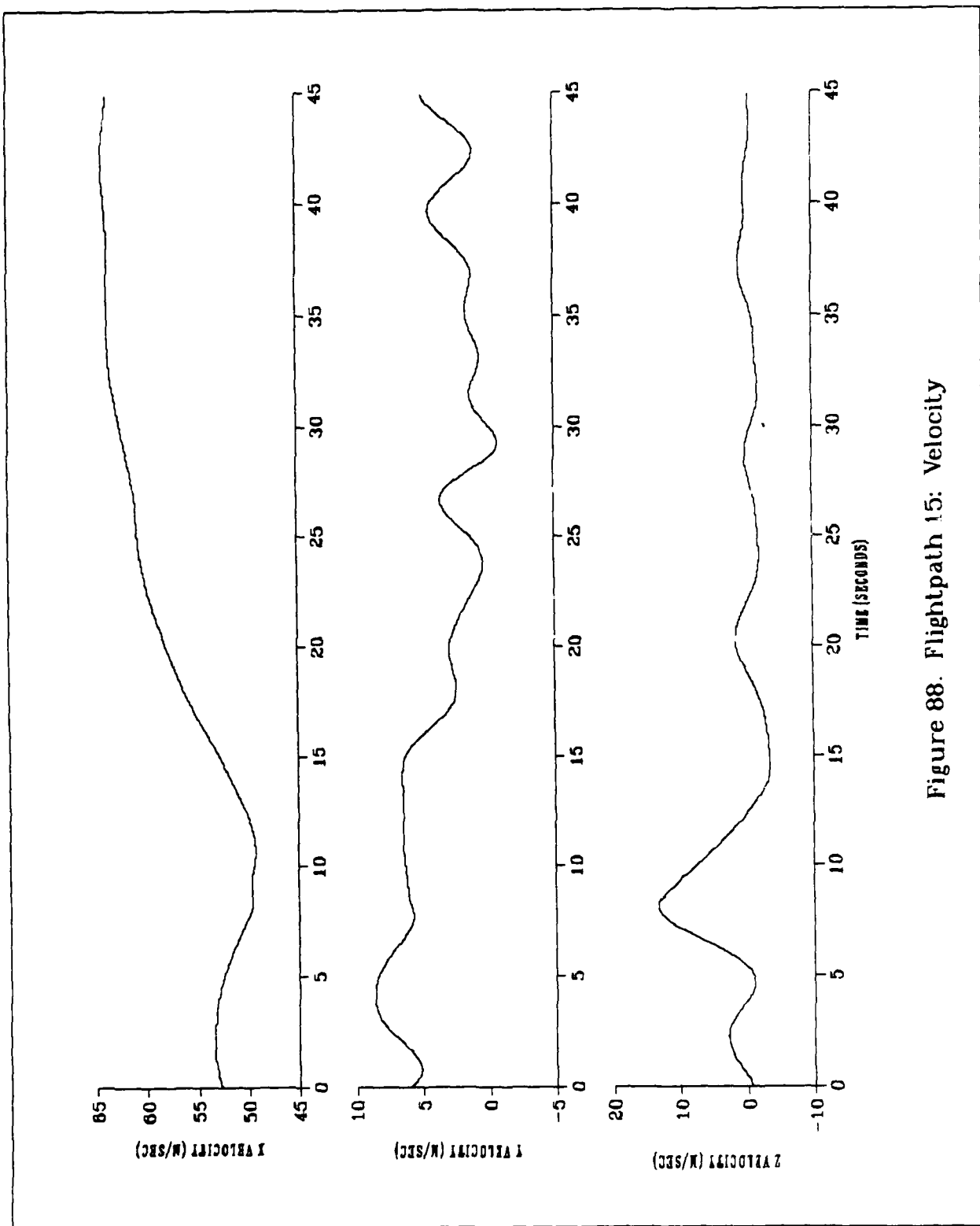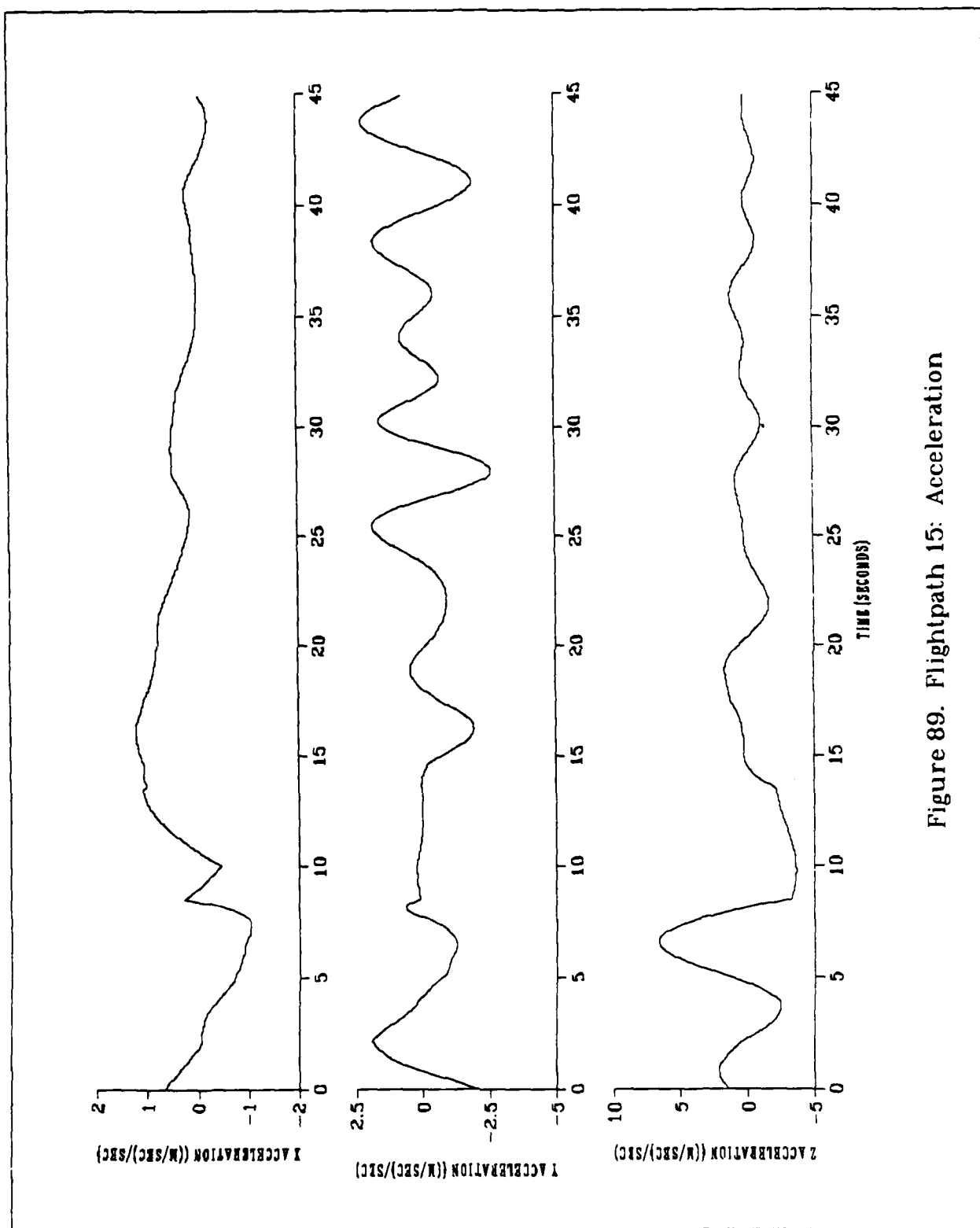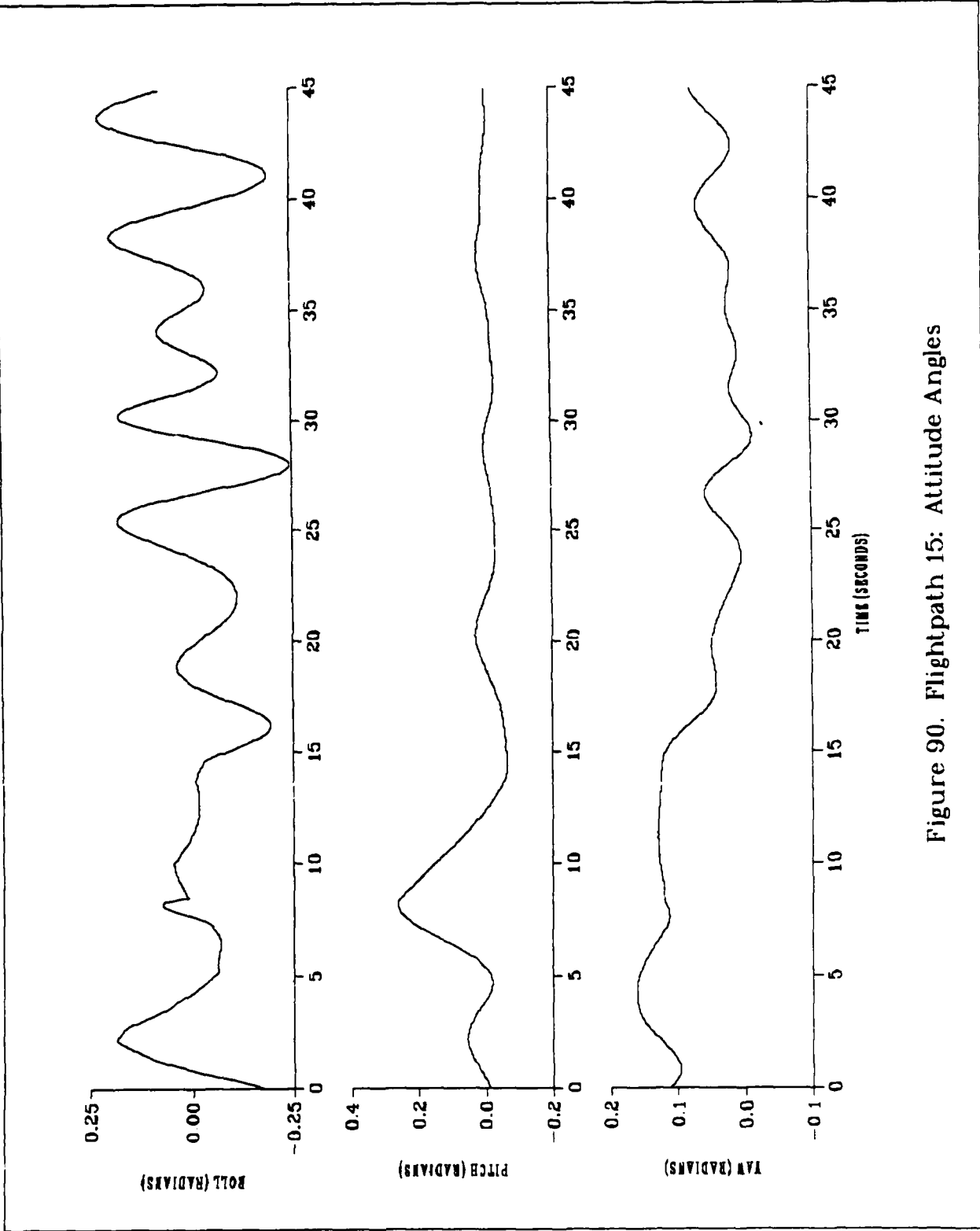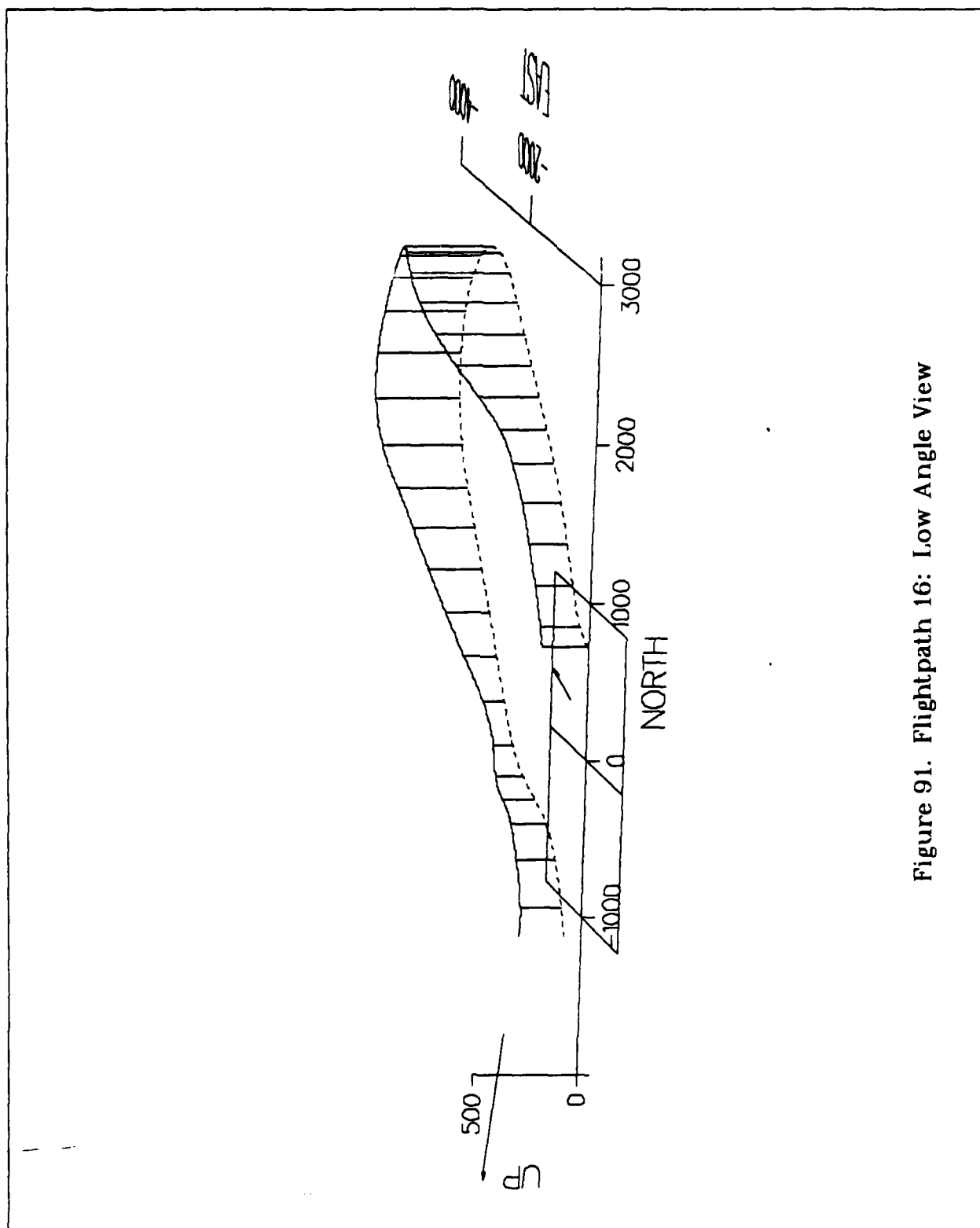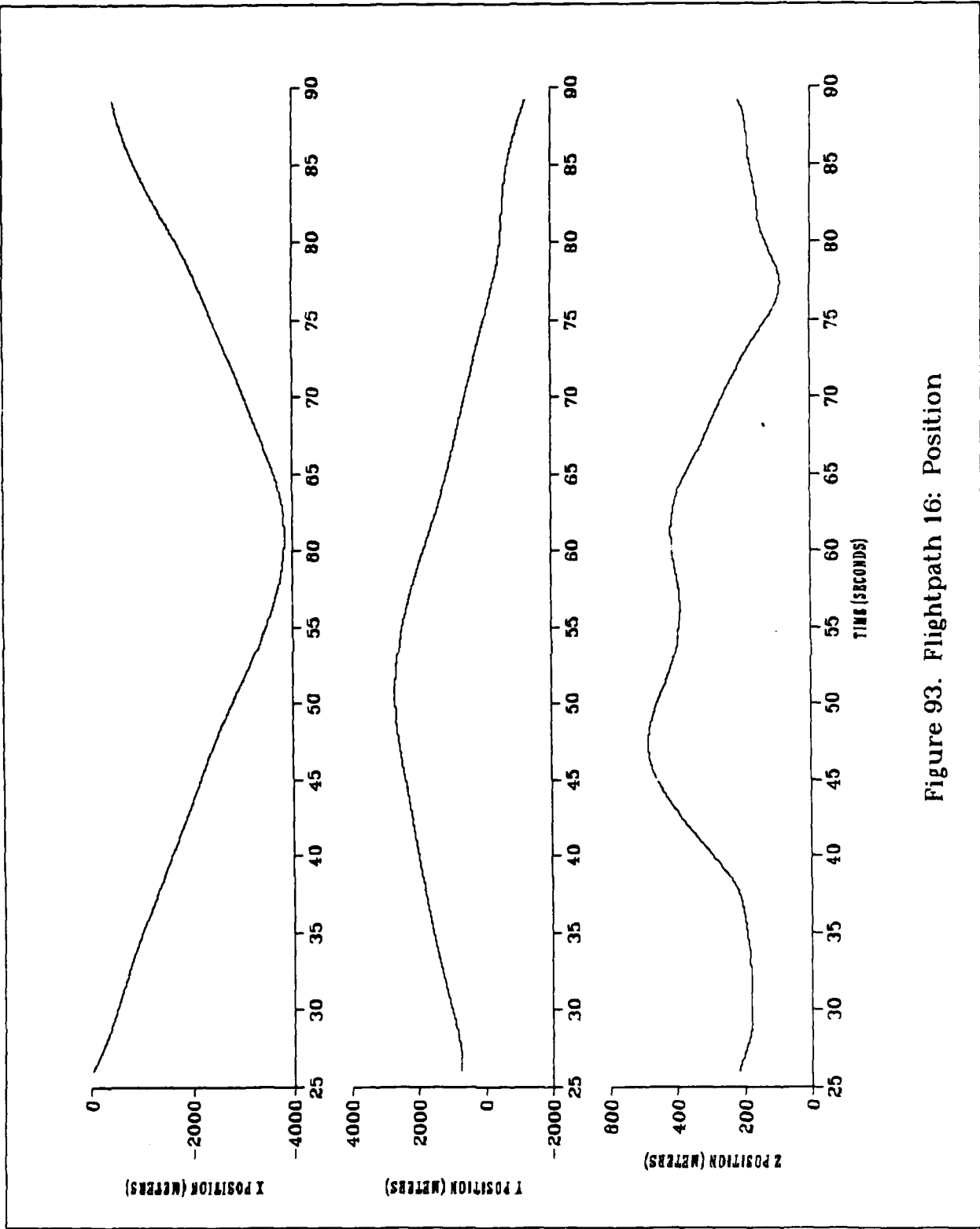
Figure 93. Flightpath 16: Position
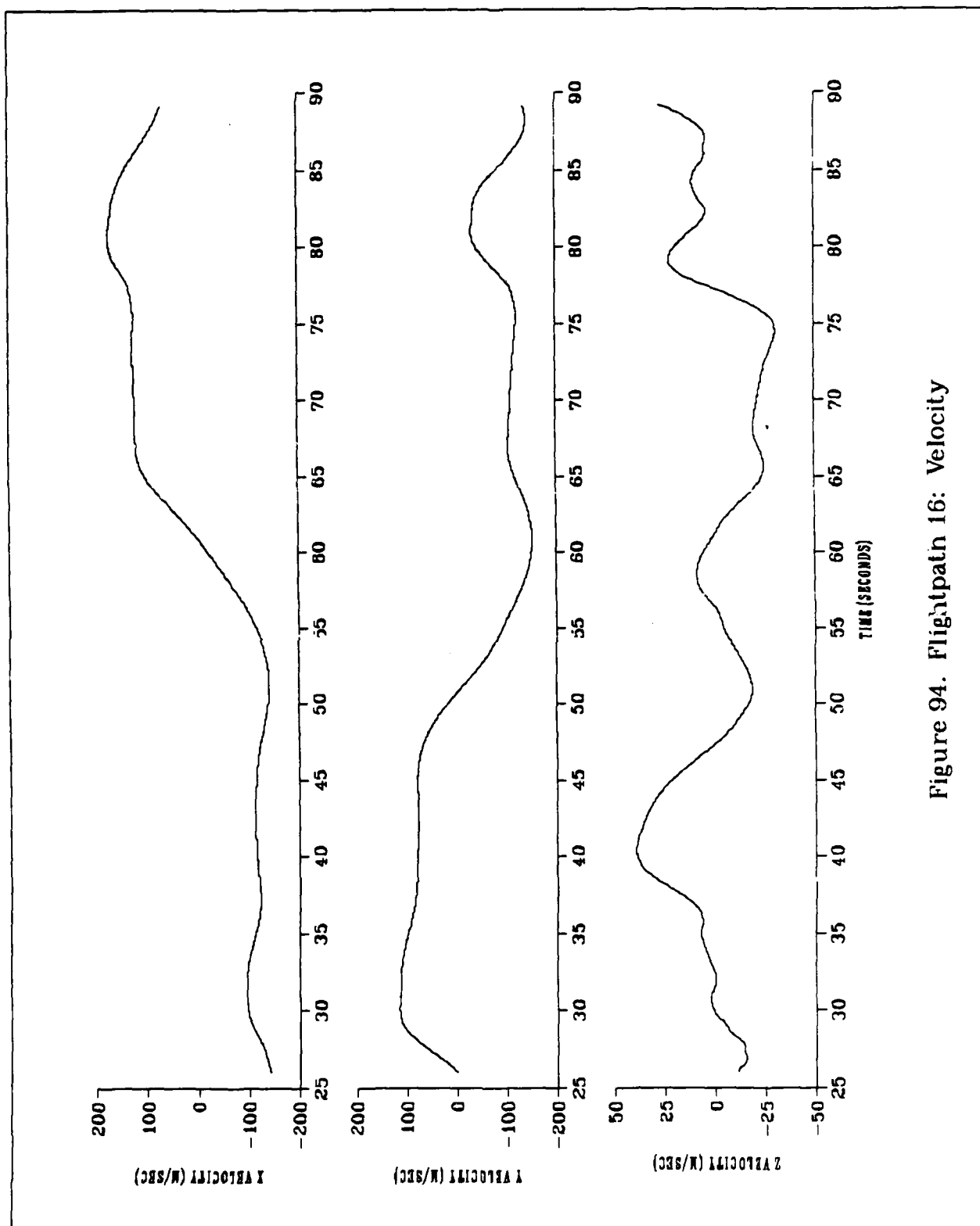
Figure 94. Flightpath 16: Velocity
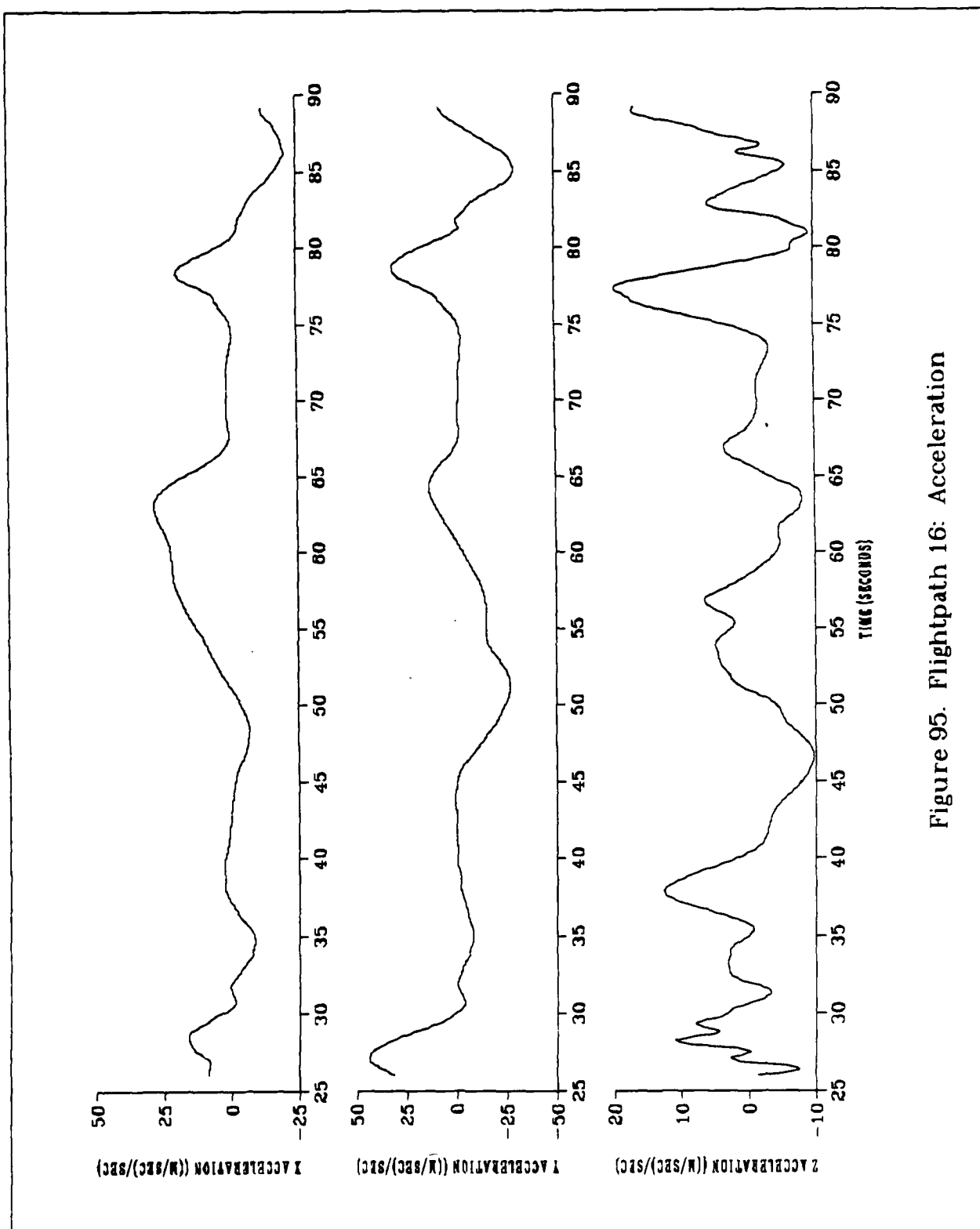
Figure 95. Flightpath 16: Acceleration
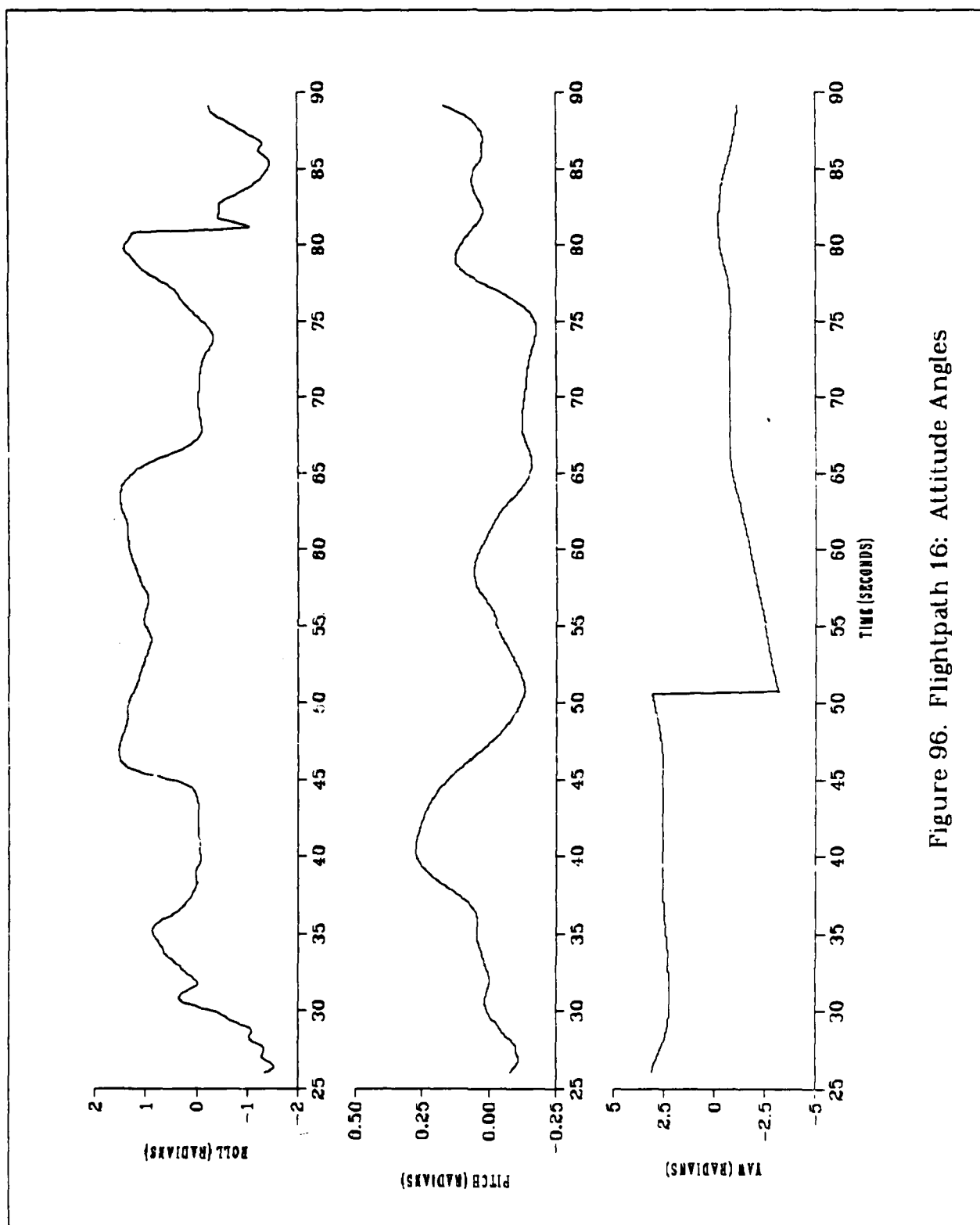
Figure 96. Flightpath 16: Attitude Angles

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